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WELCOME...

Our minds seemingly have an infinite ability to question. Some of these ponderings seem daft at first, but once you start to think about it, you realise there really is no such thing as a stupid question.

For example, outside our offices is a beautiful horse chestnut tree. While writing this, I'm watching some birds hopping through their branches. But why do some birds hop, while others run? Find out on page 56. Or maybe you're reading this as you stand in the magazine aisle at the supermarket. Is there a delicious smell wafting from the bakery? So how does your brain know it's delicious? All is revealed on page 12. Or maybe you've bought the magazine already and are now enjoying it with a glass of cola. But could you enjoy the same fizzy drink in space? Check out page 28.

Children often have incredibly enquiring minds, and their supply of 'But whys?!' is inexhaustible. So if you find yourself struggling to come up with satisfactory explanation for all their questions, then we're sure you can find the answers in *The Big Book Of Why?*, brought to you by *BBC Focus*.

But even if you don't have kids, there are oodles of facts here to feed the curious mind. We've covered all the bases, including animals, the environment, space, the human body, and much more. So get ready to start impressing your friends and family, and maybe you'll even win your next pub quiz!

Enjoy!

Alice Lipscombe-Southwell, Managing Editor

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Pop: the question
What's best for you – cola or diet cola?
See p37

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HOW GREEN IS MY VALLEY?

The buildings of Gouqi Island are slowly being consumed by a thick blanket of green. The island is located a few hours east of Hangzhou Bay in eastern China and was once home to a thriving fishing community. But as the shipbuilding and tourism industries grew, the village became deserted. With nobody left to maintain them, the buildings were soon reclaimed by the natural world.

"These buildings are covered with *Parthenocissus tricuspidata*, a relative of the grape vine and Virginia creeper," explains Dr Alastair Culham, Curator of the University of Reading's herbarium. 'It's native to China but is also widely cultivated as an ornamental climber for its red autumn foliage and was probably already planted there to decorate the houses. It's equivalent to ivy in the UK, which will soon cover a building if left alone."

PHOTO: GETTY

THE HUMAN BODY

Organ transplants, wisdom teeth, suncream protection, fingerprints, sense of smell, heart rate and music, phobias, embarrassment...

WHY DO SOME PEOPLE GET MIGRAINES?

Amazingly, the precise cause of migraines is still unknown. These intense headaches – often on one side and accompanied by nausea and sometimes visions of zigzag lines and extreme sensitivity to light and noise – must be caused by abnormal brain activity. But we just don't know what kind or whether there are many different causes.

Hormonal fluctuations, especially in oestrogen, can trigger migraines, so some women suffer more during menstruation, pregnancy or menopause. Certain foods and additives can also cause migraines, while people who diet, skip meals or consume a lot of caffeine can suffer. Disturbed sleep and jetlag can also cause them.

One rare inherited type called familial hemiplegic migraine is caused by four specific gene mutations. More common types are also associated with many different genes that affect brain function. The simplest answer lies in the family. Up to 90 per cent of sufferers have a family history of migraines.

WHY ARE SOME PEOPLE PERFECTIONISTS?

This is because of the way that genes and experience work together. Genetic effects are seen even in newborn babies, whose different temperaments show the beginnings of their personality.

Recent twin studies suggest that personality is more heritable than previously thought. Identical twins are twice as likely as non-identical twins to share particular qualities, such as determination, self-control and a sense of purpose. While perfectionism can be positive, leading to high achievement, satisfaction and self-esteem, it can also be negative with harsh self-criticism, procrastination, disappointment and depression.

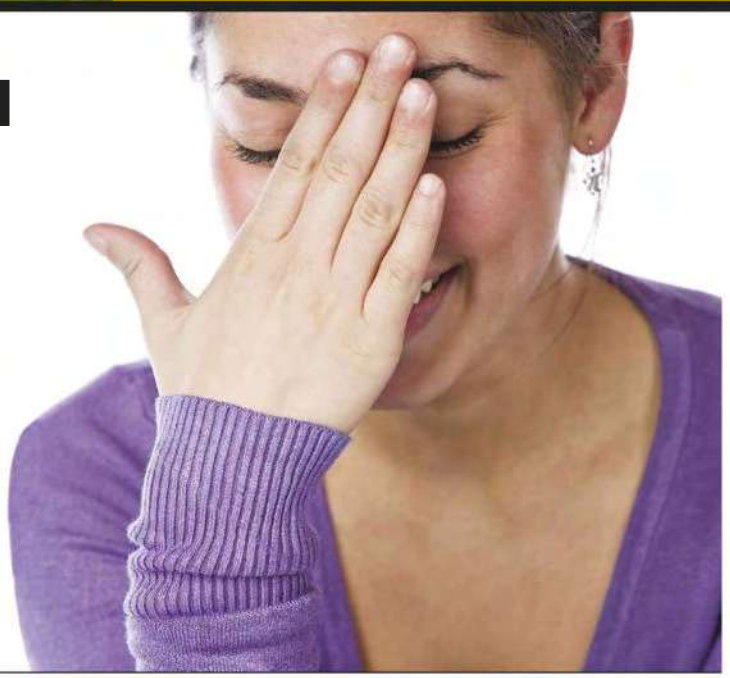
Both are related to the 'Big Five' personality traits that sum up our relatively stable adult personalities. These traits are openness, conscientiousness, extraversion, agreeableness and neuroticism. Yet all these traits are subject to the effect of life's encouraging or dispiriting experiences.

How does suncream protect you from sunburn?

Opaque sunblocks are, effectively, paint: inorganic particles of white titanium dioxide or zinc oxide suspended in a heavy oil. The oxide particles form an opaque barrier that reflects visible light and ultraviolet. Clear suncreams use organic compounds, such as phenylbenzimidazole sulfonic acid, which protects from UVB and lets visible light through. Many creams blend inorganic and organic particles to offer good protection.

Why do we go red in the face when embarrassed?

Humans seem to be the only animals to show embarrassment, leading Charles Darwin to describe blushing as "the most peculiar and most human of all expressions". Blushing makes it harder to lie, which seems like a disadvantage. However, a 2009 study by Dutch psychologists found that we are more likely to give people a second chance if they blush when they betray us. The ability to blush acts as a signal that you are sensitive to the social rule you have just broken. Psychopaths, on the other hand, do not blush at all.



PHOTOS: SCIENCE PHOTO LIBRARY, ISTOCK X4

TOP TEN

HUMAN PHOBIAS

SUFFERED FROM IN THE UK

=1. Arachnophobia
Fear of spiders
Proportion of population affected: 33 per cent

=1. Ophidiophobia
Fear of snakes
Proportion of population affected: 33 per cent

3. Astraphobia
Fear of thunder/lightning
Proportion of population affected: 15 per cent

=4. Trypanophobia
Fear of needles
Proportion of population affected: 10 per cent

=4. Claustrophobia
Fear of enclosed spaces
Proportion of population affected: 10 per cent

6. Odontophobia
Fear of dentists
Proportion of population affected: 9 per cent

7. Aviophobia
Fear of flying
Proportion of population affected: 7 per cent

8. Acrophobia
Fear of heights
Proportion of population affected: 5 per cent

9. Cynophobia
Fear of dogs
Proportion of population affected: 3 per cent

10. Agoraphobia
Fear of public spaces
Proportion of population affected: 2 per cent

Can an organ be transplanted more than once?

Yes. Sometimes patients will receive heart or liver transplants but die anyway within a few weeks and, in very rare cases, the donated organ was still healthy enough to be worth re-transplanting to a new patient. In 2012, a 27-year old man from the US received a kidney transplant but then had it removed again two weeks later because the disease he was suffering from was damaging the kidney. Doctors rescued it in time and gave it to a 67-year old man instead, returning the first patient to dialysis treatment.

ARE WOMEN REALLY BETTER AT MULTI-TASKING?

Maybe, but the brain cannot handle two complex tasks at once, so what looks like clever multi-tasking is more often switching quickly between two or more tasks. This is an inefficient way of working because the brain has to both decide when to switch and remember each task. In many laboratory tests, men and women do equally well. In a more realistic study, men and women under time pressure had to juggle simple mathematics problems, answer the phone and decide how to find something lost in a field. During the study, the women were found to be calmer and better organised than the men. But even if this difference is real, we still don't know whether it is biological or culturally imposed.

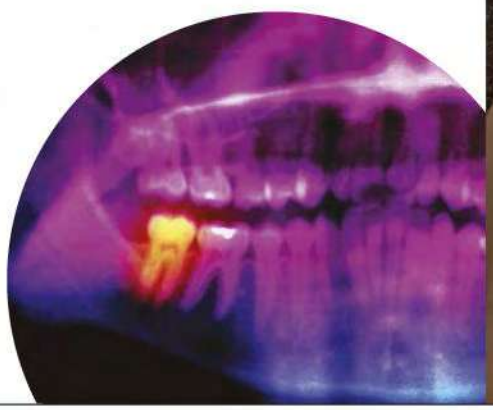
PHOTOS: GETTY, ISTOCK X10

Why are some people always so angry?

Medical reasons for anger include a hyperactive thyroid, cardiovascular disease, diabetes and dementia. Healthy people may resort to anger because they can't deal with fear, disappointment, frustration or embarrassment. They want to control the world and cannot, or they feel a failure and blame others for everything that goes wrong. This may have roots in past trauma or in poor parenting that leaves children ill-equipped to understand and cope with their own and others' varying emotional states. Anger often harms the angry person more than anyone else. There's no quick fix, but a good start is to recognise your own anger and establish what triggers it as soon as it begins.

WHY DO WE HAVE WISDOM TEETH?

We evolved from hominids that had longer jaws for chewing raw meat and plants. Extra molars are an advantage, but they don't emerge until adulthood, allowing the jaw time to grow large enough to accommodate them. We don't need wisdom teeth any more, nor do we have enough room for them. But dentistry offers a quicker fix than evolution.

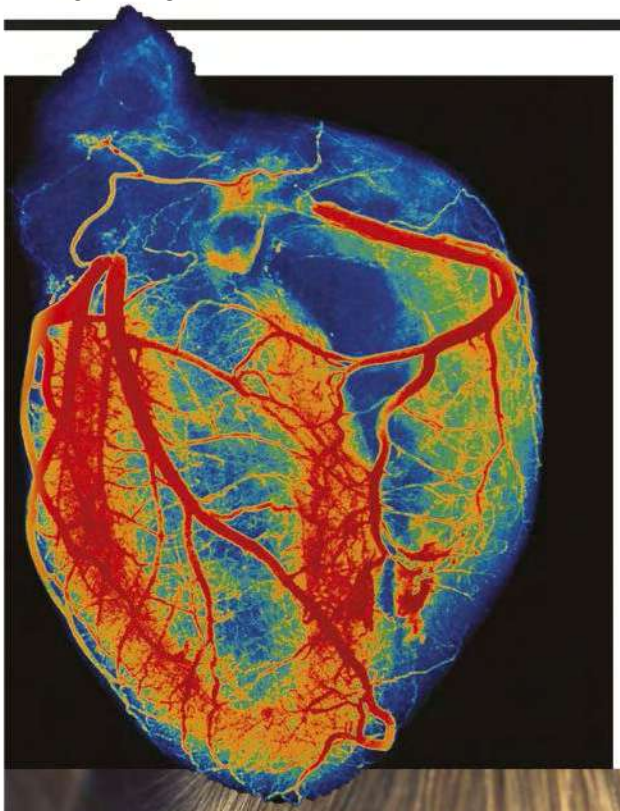


How much skin does the average human shed in their life?

According to a 2011 study published in the journal *Environmental Science & Technology*, we shed between 0.03-0.09g of skin every hour of every day. That sounds like almost nothing, but over the course of a lifetime it adds up to about 35kg, or roughly half your bodyweight. Most of this is in the form of tiny flakes, which make up a major constituent of house dust.

Interestingly, the same study found that the squalene oil on shed skin reacts with harmful ozone in houses, offices and aeroplanes, so dust can actually improve the air quality.

PHOTOS: GETTY, ISTOCK, SCIENCE PHOTO LIBRARY



DOES A HUMAN HEART HAVE A FINITE NUMBER OF BEATS?

Yes. At an average of 80 beats per minute, most of us will manage less than four billion beats in our lives. But you don't die because you run out of heartbeats; you run out of heartbeats because you die.

Among mammals, the number of heartbeats over the lifespan of different species is fairly constant. So hamsters' hearts beat 400 times a minute and they live for about four years, which is 840 million beats, while an elephant manages 35bpm for 35 years, or about 640 million beats in total. Those numbers are similar, but that's just because animals with faster heart rates are also smaller and more at risk from predation and starvation. Their lifespans have evolved to compensate for this by reproducing early and often – they 'live fast, die young'.

Heart muscle can only repair itself very slowly, so eventually every heart will wear out, but it won't do so after a specific number of beats.

HOW DOES THE BRAIN DISTINGUISH BETWEEN GOOD AND BAD SMELLS?

Molecules in the air dissolve in mucus inside the nose and are detected by olfactory receptors that send signals to the brain. In primates, including humans, there are two pathways. One goes to the olfactory cortex, the other passes to the hypothalamus, which is involved with emotion, motivation and memory. This part is responsible for whether we like or reject a smell. It may also be why smells and memory have a close association.

Although humans have a comparatively weak sense of smell, it remains important. Babies who are just a day old show expressions of disgust when they smell fish or rotten eggs, while children can distinguish between the smell of their siblings and other children of the same age. Similarly, a baby recognises its mum's smell and a mother recognises their baby's. Even the humble fruit fly has complex olfactory processing. It has one system that identifies a smell and another that categorises smells as good or bad.

IN NUMBERS

8.8 cm

The length of the longest nose on a living human, as measured from bridge to tip. It belongs to Mehmet Ozyurek from the Turkish city of Artvin.

PHOTOS: SCIENCE PHOTO LIBRARY

DID YOU KNOW?

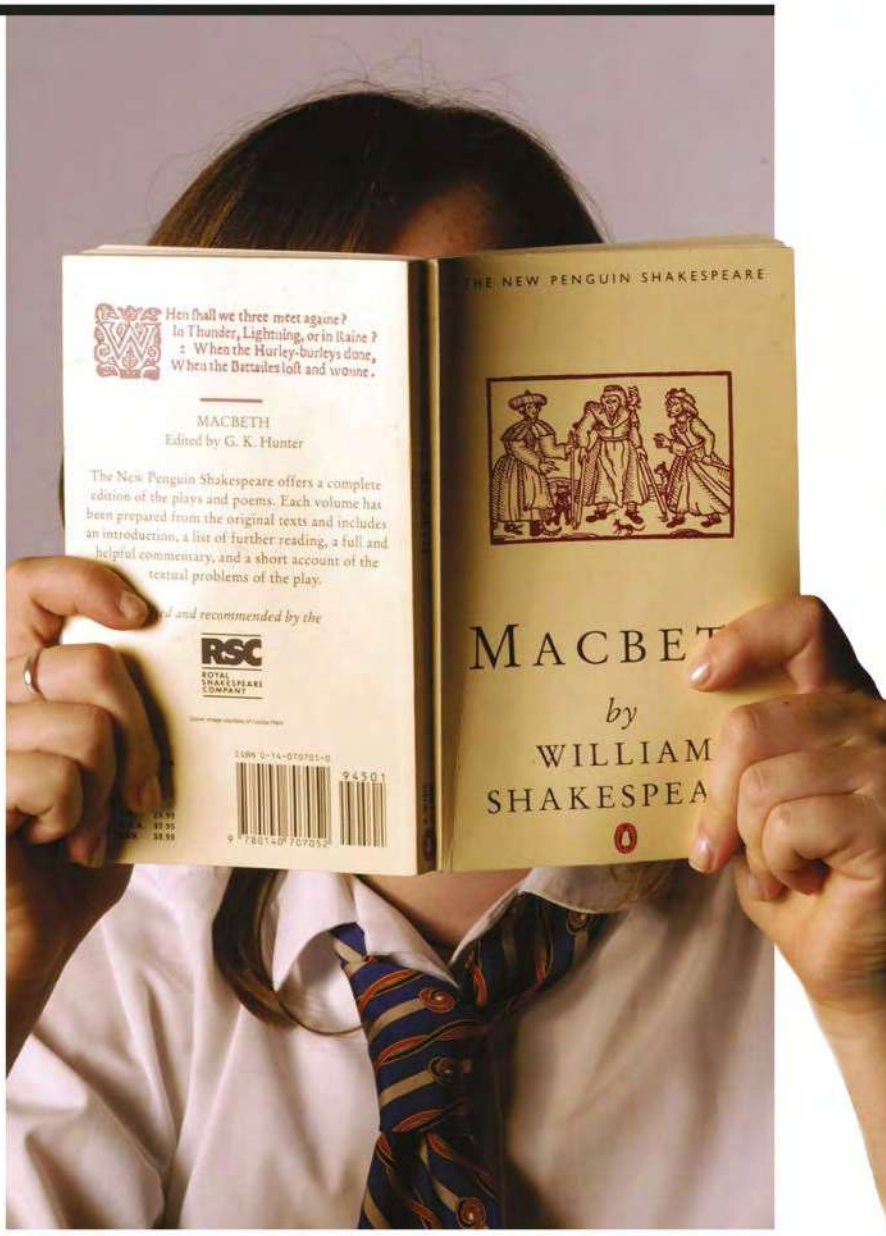
While the human brain makes up just 2 per cent of total body weight, it uses up between 20-25 per cent of the body's energy.

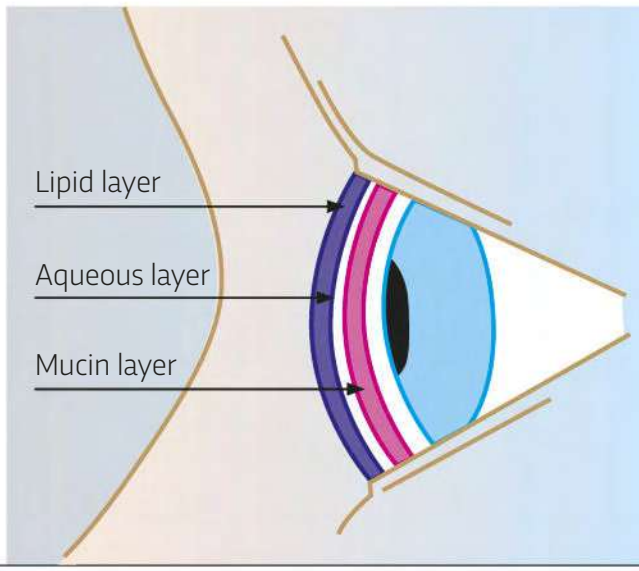
Why do we get a mental picture when reading?

Reading is a complex, multi-layered process, starting with detecting letters, recognising words and groups of words, then analysing sentence structure and meaning. Different areas of the brain build up information about the scenes, actions and characters, relating them to what you already know and feel.

And it's not just your brain that's active as you read. Your lips and tongue may even move, your spine might tingle and your muscles may tense in response to a particularly gripping story. All of these reactions contribute to what we think of as pictures in our head. Yet, in reality, our brains probably contain no such thing. Indeed, recent theories treat vision more like an interaction with the world rather than a picture-making process.

Strangely enough, written descriptions that contain more detail don't necessarily result in richer or more satisfying mental imagery in the reader's brain. Sometimes, the simplest descriptions allow you to create your own imagined world with far more emotional involvement.





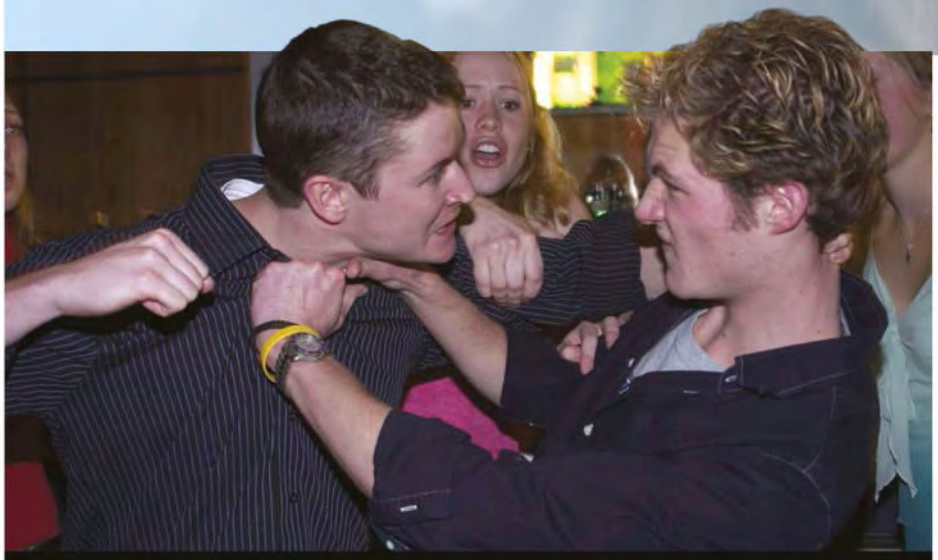
Why do we get dry eyes?

Your eyes are covered in a thin film of fluid in order to make the surface optically smooth. It is secreted by the cornea and the lacrimal glands in the corner of your eyes. Dry eye, or *kerato-conjuctivitis sicca*, happens when you don't make enough tears or you don't blink enough. Blinking is crucial because the tears can't spread fast enough by themselves to keep up with the rate of evaporation. Driving, reading or staring at a computer screen all reduce your blink rate. Tear production slows as we age, but can also be reduced by damage to the corneal nerves from contact lenses or eye surgery.

PHOTOS: ALAMY

WHAT MAKES A PERSON'S VOICE UNIQUE?

Like a musical instrument, the sound of your voice is determined by the shape and size of its parts. The length of your vocal cords, the shape of your nose and the contours of your throat all contribute. The exact timing of the contractions of muscles in your mouth, tongue, larynx and diaphragm are different for everyone – even when they are saying the same words. These things are affected by the accents or cultures that surrounded us when we learned to speak.



What makes some drunk people argumentative and troublesome?

It's down to the effect of alcohol on one particular area of the brain. The prefrontal cortex is important for keeping impulsive behaviour under control. Alcohol interferes with this, leading people to show poorer judgment and worry less about the effects of their actions. They misinterpret people's intentions and easily lose their temper.

Low levels of serotonin (a mood-balancing chemical) and higher levels of dopamine (a chemical relating to pleasure) are also associated with alcohol-induced violence, but not everyone is affected this way.

Expectation and upbringing are important factors, too. Adversity in early life can decrease serotonin levels, while drinking when young can damage the brain's frontal lobes. Also, people who witness alcohol-fuelled violence as children are more likely to become violent when drunk.

CAN FINGERPRINTS CHANGE DURING A LIFETIME?

The pattern of loops and whorls on your fingerprints was fixed three months before you were born. You can scar your fingerprints with a cut, or temporarily lose them through abrasion, acid or certain skin conditions, but fingerprints lost in this way will grow back within a month. As you age, skin on your fingertips becomes less elastic and the ridges get thicker. This doesn't change your fingerprint, but it's harder to scan or take a print from it.

What happens in our brain when we learn languages?

Specific brain areas increase in size and function, including Broca's area, which is usually in the left hemisphere and involved in language production. When children grow up bilingual, both languages are processed in the same area. Yet, when adults learn a second language, a separate area develops close to the first.

Some adults learn more quickly than others and one study showed differences in the brain areas that changed: the hippocampus and Broca's area altered most in the fast learners and the motor cortex in slower students. Some effects depend on the person's first language. For example, native Japanese speakers cannot readily distinguish 'r' and 'l' when learning English because, in their brains, both these sounds activate the same area. In native English speakers, however, the sounds activate distinct areas.

More generally, learning a new language improves brain function, providing better memory, more mental flexibility and creativity, and can even delay the onset of dementia.

PHOTOS: ALAMY X2, ISTOCK X3

DID YOU KNOW?

The average human body is estimated to contain more than 95,000km of blood vessels.

Is it possible to take too many vitamins?

Most definitely. The body normally regulates your levels of vitamins A, D and E, which you eat as part of a healthy diet. If you consume the vitamins in tablet form, you bypass this regulation mechanism and excess vitamins get stored in the liver, gradually building up over time. A daily dose of 2,500mg of vitamin A for six months is enough to give you chronic vitamin A toxicity, with

symptoms including blurred vision, hair loss and peeling skin. But you'd need to take more than 37 cod liver oil capsules a day to reach that quantity.

Taking vitamin supplements may even be bad for you – even at doses well below the toxic threshold. Probably the hardest one to overdo is vitamin C. The recommended daily intake for adults is 65-90mg (roughly one orange), but you can tolerate up to 2,000mg a day without any ill effects. At very high doses, vitamin C eventually causes diarrhoea, heartburn and kidney stones.

IN NUMBERS

7,000

The number of blood donations taken in the UK every day. One in four of us will require a blood transfusion at some point in our lives.

DOES MUSIC AFFECT OUR HEART RATE?

You don't need a scientific study to realise that a rousing tune gets your blood pumping – and lots of studies have measured a very definite physiological effect. Calming classical music lowers blood pressure and heart rate, while pounding heavy metal raises it. This effect is more pronounced in professional musicians, but it affects everyone to some degree, even if you're listening to music that you don't like.

It's not clear why this happens, but it might be something we learn in the womb. Foetuses can hear from the end of the second trimester (six months into the pregnancy) and every baby is exposed to the sound of its mother's heartbeat. When a pregnant mother is stressed, her heartbeat rises and her baby may come to associate that sound with the stressed sensation. It's possible that our reaction to music is a sort of empathic memory from that shared time.

PHOTOS: ISTOCKX2

WHY DO WE FORGET OUR DREAMS SO QUICKLY?

Psychologists still don't understand the function of dreaming. However, it almost certainly relates to memory, either by helping to consolidate the day's events or enabling us to forget unwanted detail so we don't become overloaded. In this case, recalling our dreams might not actually be helpful, though. During vivid dreaming, serotonin and noradrenaline levels are low and this might affect recall.

But perhaps the main reason is that most of our waking memories make sense and are interlinked. When remembering what you had for breakfast today, you can probably link that to memories of getting up, feeding the cat and other small events. But dreams are usually illogical and their events are unrelated. So when we try to recall them, we can't follow a sensible thread and the previously vivid details just slip away.

WHY DO WE CRY WHEN WE'RE IN PAIN?

For helpless infants, crying is a distress signal to encourage their parents to make things better again. In adulthood, most wild animals suppress these signals because they don't want to show their vulnerability to predators, or rivals of their own species. To some extent, this instinct persists with humans as well, which could be one reason why men tend to cry less than women. But compared to most mammals, we are a highly social species. However much it might hurt your pride, crying in pain summons help and warns people of danger, both of which are useful evolutionary traits.

Why do we lose the sound of our voice when we whisper?

The sound of your voice is created when air vibrates the larynx's vocal folds. The pitch depends on how tightly these folds are stretched by your throat muscles. When you whisper, the vocal folds are slightly held apart and stretched so tightly that they can't vibrate. The air passes through in a rush that creates a mix of different frequencies, heard as a high-pitched hiss.

PHOTOS: ISTOCKX2

TALK TO THE HAN

Say hi to Han, a state-of-the-art robotic head made by Hanson Robotics. His skin has been created using a high-tech flexible material called Frubber (aka flesh rubber) and it's even dotted with pores to give it a more human appearance. But Han doesn't just look human; he can act the part too. Cameras hidden within his eyes and chest allow him to recognise faces and make eye contact with those around him. Once locked onto a subject, he can respond to their actions by altering his expressions and even engaging them in banter.

"The growing number of elderly in our societies and our ever-increasing life expectancies are adding pressure to social services," explains Angelo Cangelosi, Director of Plymouth University's Centre of Robotics and Neural Systems. "Robot companions, both in care homes and in private residences, can play important roles in supporting and monitoring health. However, robot companions should not be seen as a substitute of family relatives, or of social care and health workers."

PHOTO: CAMERA PRESS

SPACE

Tallest rockets, black holes, Universe expansion, lightning in space, gravitational pull, dark matter, asteroids, constellations, the Sun's spin cycle...

WHAT CAUSED THE BIG BANG?

The Big Bang is the moment that space and time (or 'space-time') came into existence. Before the Big Bang there was no space or time. So, it is actually meaningless to ask what caused the Big Bang to happen – there was no universe in which that cause could have existed. This might seem like a bit of a cheat, but there are other good reasons to suppose a cause for the Big Bang might not exist. Quantum physics has shown us that some events have no cause at all. Things can happen randomly, spontaneously, and for no particular reason. This unpredictable and 'causeless' nature of the Universe is experimentally verified but has nothing to do with our inability to observe correctly – it is a fundamental property of the Universe. So, although there may have been a cause for the Big Bang that we are unaware of, modern cosmology neither defines nor requires one.

DID YOU KNOW?

The most heavily cratered moon is Callisto, which is in orbit around Jupiter. Its surface is 100 per cent covered in craters.

Can stars collide?

In general, distances between stars are so vast that it is unlikely that any two will ever meet and collide. But, in some places, notably in globular clusters, stars can be crowded together much more tightly and, indeed, may well collide with each other. Many clusters contain very large, hot stars known as 'blue stragglers', which should have detonated as supernovae billions of years ago. It's believed these stars formed more recently as the result of collisions and mergers of normal stars. It's also probable that stars collide in other star-rich places, such as the central regions of galaxies. Binary stars can coalesce as one star reaches the end of its life, expands and consumes its partner.

IN NUMBERS

13.1 BILLION

The number of years it took for light to reach Earth from the most distant known galaxy. The light was emitted only 700 million years after the Big Bang.

WHAT HAPPENS IF YOU FIRE A GUN IN SPACE?

Assuming you are floating freely in space, the gun will work just as it does on Earth. Modern ammunition contains an oxidising agent to trigger the explosion, so a gun will still fire, despite the lack of oxygen. The bullet, though, will continue moving for thousands of years, eventually coming to a stop due to the friction from the diffuse material found in 'empty' space (or when it encounters another object). You will also begin to move, in the opposite direction to the bullet, at a velocity of several centimetres per second.

What causes a halo around the Sun?

The appearance of a huge, perfectly circular halo round the Sun in Mexico in 2015 sparked rumours of the impending end of the world. In reality, it was the product of sunlight being refracted through hexagonal ice crystals high in the atmosphere. Water droplets can do the same, producing a smaller, more colourful halo.

PHOTOS: ISTOCK, GETTY X2, NASA/HUBBLE SPACE TELESCOPE

DID YOU KNOW?

The spacesuit worn by Neil Armstrong for the 1969 Moon landing was made by a bra manufacturer.

WOULD IT BE POSSIBLE TO FLY A DRONE ON MARS?

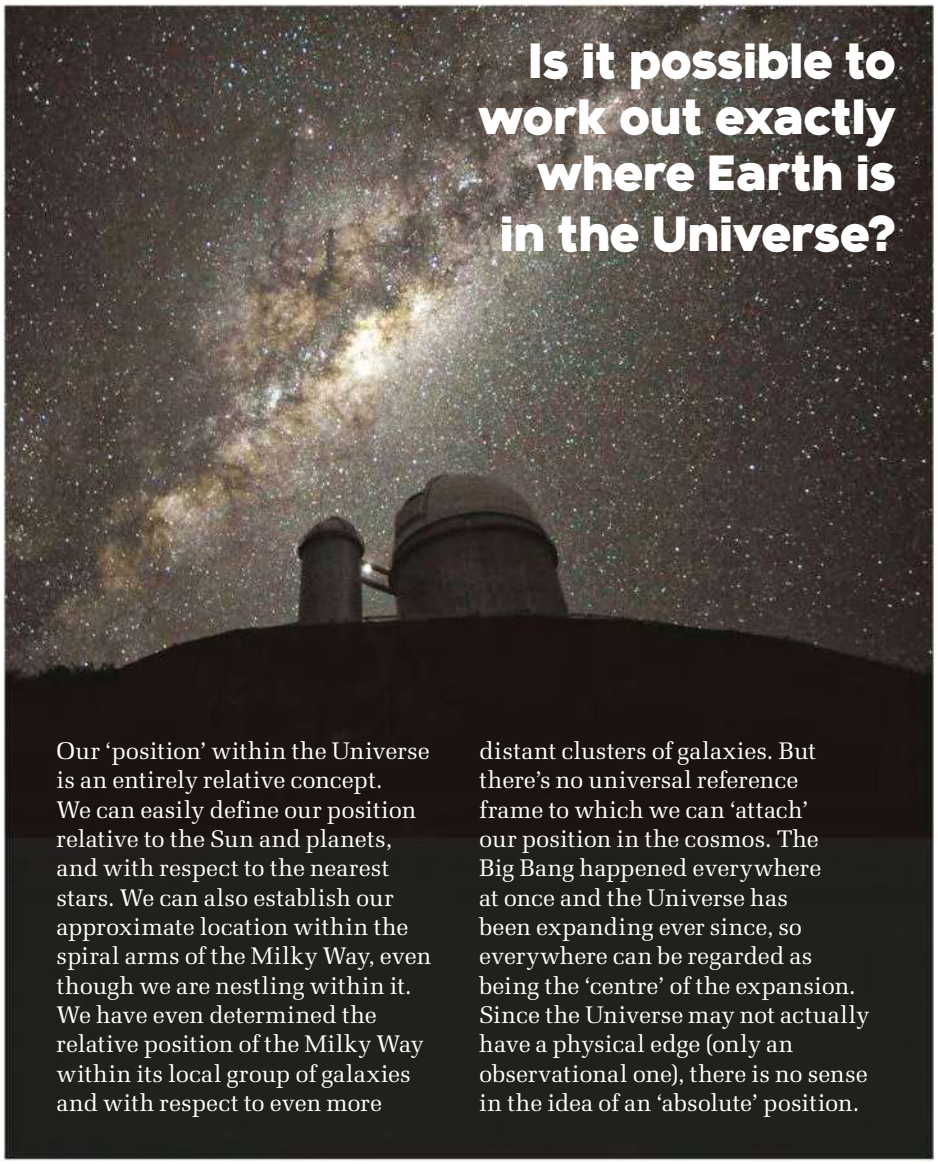
Drones come in various guises, the simplest being those propelled by electric-powered rotors. And, in principle at least, there's no reason why a modified one shouldn't be able to zoom around the Red Planet – though the practicalities are pretty challenging.

An Earth-bound drone is kept aloft by directing air downward, with the resulting thrust counteracting the force of gravity. The good news is that the surface gravity on Mars is barely one-third that of the Earth, so the rotors don't have to work so hard to combat its effect. The bad news is that the Martian atmosphere is far more tenuous than Earth's, with a density 60 times lower. So for a given weight of drone, the rotors must be much more effective at generating the downward thrust. That means increasing the size of the rotors, their number, their spin-rate – or some combination. Doubling the number of rotors and their length might do the trick, but the result would be pretty unwieldy. Then there's the problem of powering the thing: the Red Planet gets less than half the level of solar energy we do. It's all possible, and NASA is looking into it, but perhaps a mini airship design would be more practical.

WHY DON'T PLANETS TWINKLE?

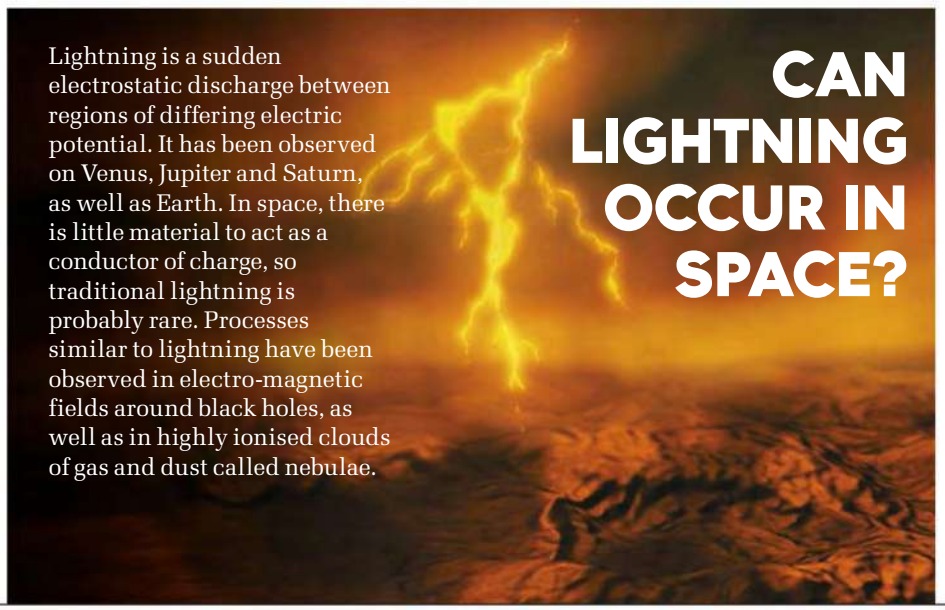
Earth's atmosphere is in constant motion and the density of its numerous layers can vary rapidly. So the refraction (or bending) that a star's light experiences as it propagates through the atmosphere is also constantly changing. This means that the apparent position and brightness of a star changes slightly from moment to moment. This makes the star appear to wobble or 'twinkle'.

However, a star is so far away that it is just a point of light, whereas a planet, being so much closer, is a tiny disc of light. Although your eyes can't resolve the disc unaided, the extent of the planet on the sky is generally much larger than the size of the atmospheric variations which cause twinkling. So, although planets do actually twinkle to some extent, it is much less noticeable than it is for stars.



Is it possible to work out exactly where Earth is in the Universe?

Our 'position' within the Universe is an entirely relative concept. We can easily define our position relative to the Sun and planets, and with respect to the nearest stars. We can also establish our approximate location within the spiral arms of the Milky Way, even though we are nestling within it. We have even determined the relative position of the Milky Way within its local group of galaxies and with respect to even more distant clusters of galaxies. But there's no universal reference frame to which we can 'attach' our position in the cosmos. The Big Bang happened everywhere at once and the Universe has been expanding ever since, so everywhere can be regarded as being the 'centre' of the expansion. Since the Universe may not actually have a physical edge (only an observational one), there is no sense in the idea of an 'absolute' position.



CAN LIGHTNING OCCUR IN SPACE?

Lightning is a sudden electrostatic discharge between regions of differing electric potential. It has been observed on Venus, Jupiter and Saturn, as well as Earth. In space, there is little material to act as a conductor of charge, so traditional lightning is probably rare. Processes similar to lightning have been observed in electro-magnetic fields around black holes, as well as in highly ionised clouds of gas and dust called nebulae.

TOP TEN

TALLEST SPACE ROCKETS

1. Saturn V
Height: 110.6m **Country:** USA
Total launches: 13
First flight: 9 November 1967
Status: retired

2. N1
Height: 105m **Country:** USSR
Total launches: 4 (all exploded)
First flight: 21 February 1969
Status: retired

3. Delta IV
Height: 72m **Country:** USA
Total launches: 26
First flight: 11 March 2003
Status: active

4. Falcon 9
Height: 68.4m **Country:** USA
Total launches: 9
First flight: 4 June 2010
Status: v1.1 active; v1.0 retired

5. Long March 2F 'Shenjian'
Height: 62m **Country:** China
Total launches: 11
First flight: 19 November 1999
Status: active

6. Zenit
Height: up to 59.6m **Country:** USSR
Total launches: 82
First flight: 13 April 1985
Status: active

7. Atlas V
Height: 58.3m **Country:** USA
Total launches: 46
First flight: 21 August 2002
Status: active

8. H-IIB
Height: 56.6m **Country:** Japan
Total launches: 4
First flight: 1 September 2009
Status: active

9. Proton
Height: 53m **Country:** USSR
Total launches: 397
First flight: 16 July 1965
Status: active

10. Ariane 5
Height: up to 52m **Country:** Europe **Total launches:** 73
First flight: 4 June 1996
Status: active

PHOTOS: SMITHSONIAN NATIONAL AIR AND SPACE MUSEUM, GETTY, NASA, ALAMY

WHY DO PLANETS TRAVEL SO FAST?

If we choose a suitable reference point to which we can relate the motion of Earth, we can deduce that our planet spins at about 1,609km/h (1,000mph) at the equator. It travels around the Sun at approximately 106,217km/h (66,000mph), moves around the centre of the Milky Way galaxy at about 777,000km/h (483,000mph) and travels towards the Virgo galaxy cluster at about two million km/h (1.3 million mph). All of these motions are a result of the gravitational interaction of astronomical bodies and the 'law of conservation of angular momentum'.

During the Solar System's formation, the momentum of the cloud from which Earth formed was conserved as it collapsed, resulting in high speeds. The same is true of the Milky Way. As the galaxy collapsed from a huge cloud of spinning gas, it span ever faster and the stars formed within it retained those high orbital speeds.

IN NUMBERS

$33.31

The amount that astronaut Buzz Aldrin was reimbursed for his travel expenses on the Apollo 11 mission to the moon in 1969.

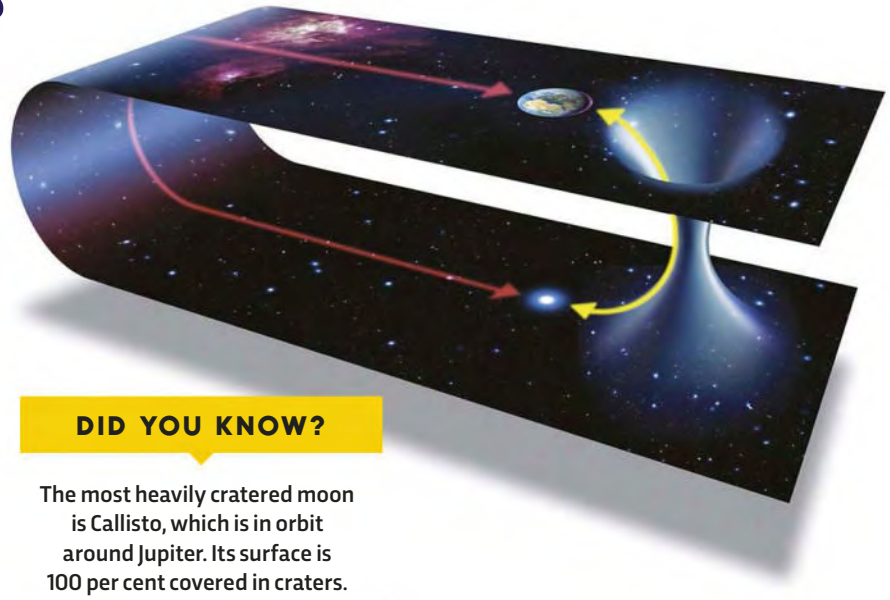
What is the biggest known star?

Astronomers cannot be absolutely sure which of the known stars are the biggest or most massive. The largest known star by radius is generally accepted as UY Scuti, which is a red hypergiant star about 9,500 light-years from Earth. Its radius is probably 1,708 times the Sun's (more than a billion kilometres). The most massive star is probably RMC 136a1, a Wolf-Rayet star about 165,000 light-years from Earth. Its mass is about 256 times that of the Sun.

PHOTOS: ISTOCK, HAKTARFONE/WIKIPEDIA

Could black holes be portals to other universes?

While the idea that black holes may connect with other regions of the Universe, or other universes entirely, has been considered in great depth, this is pure speculation. Some physicists have attempted to combine quantum mechanics with the General Theory of Relativity, concluding that black holes may not contain a 'singularity', the point at which density becomes infinite. This opens up the possibility that black holes are shortcuts to other universes. Actual tunnels through space-time, called 'wormholes', may be a better bet for traversing between universes. But, although predicted by Einstein, no wormholes have yet been discovered. Doubts remain that they could occur naturally at all.



DID YOU KNOW?

The most heavily cratered moon is Callisto, which is in orbit around Jupiter. Its surface is 100 per cent covered in craters.

Why can't we measure dark matter?

Dark matter *is* measurable – it is just not visible. And it is invisible because it is 'dark'. Astronomers infer the presence of dark matter because it explains how galaxies manage to hold themselves together, how gravitational lenses work and the observed temperature distribution of hot gas seen in galaxy clusters. The conclusion is that more than 80 per cent of the mass of the Universe is in a form we simply can't see. However, despite its ubiquity, astronomers have no real idea what constitutes dark matter. It may include subatomic particles, such as heavy neutrinos, or other hypothetical particles like axions.

Currently, astronomers believe most dark matter consists of new elementary particles called weakly-interacting massive particles, which apparently do not interact with electromagnetic radiation or atoms. They are therefore invisible to conventional means of detection.

PHOTOS: SCIENCE PHOTO LIBRARY, NASA

WHAT WAS THE UNIVERSE LIKE BEFORE THE BIG BANG?

Modern physics cannot define events that occur before the Big Bang. Our theories break down completely at the moment of 'creation'. Hence there is no observational proof that there were such things as 'time' or 'space' before the Big Bang. But this hasn't stopped some scientists speculating on pre-Big Bang physics. It may be that nothing existed before the Big Bang. Perhaps previous universes existed, or versions of our own, or many universes with different physical laws.

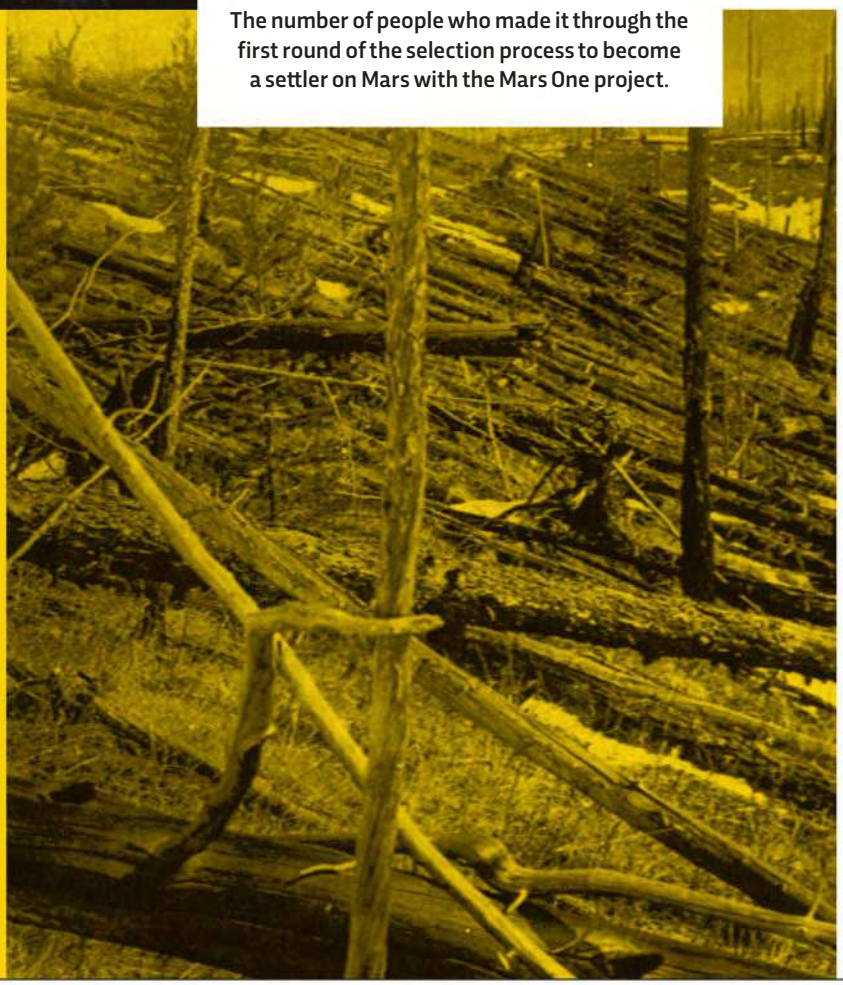
What are constellations?

Constellations are merely patterns of stars that were originally associated with mythological or astrological figures. Usually the only connection between the stars in a constellation is that they appear in the same part of the sky. They may, in actual fact, be located at very different distances. In modern astronomy, the constellations are defined not by the actual pattern of stars, but by a particular area of the sky with defined borders.

IN NUMBERS

1,058

The number of people who made it through the first round of the selection process to become a settler on Mars with the Mars One project.



WHERE IS THE LOUDEST PLACE IN THE UNIVERSE?

Sound is the movement of a pressure wave through matter. Since space is almost (but not quite) a complete vacuum, sound does not propagate easily through it. However, where matter is more dense – such as in the atmospheres of planets, within stars, in gas clouds or in environments surrounding black holes – sound waves are thought to be common.

The 'loudest' sounds in the Universe are the ones carrying most energy. A rough estimate of the loudness of the Big Bang is about 100dB to 120dB. Although this is near the human ear's pain threshold, it is by no means the loudest thing known to us. It is estimated that the loudest thing on Earth was probably the explosion of the Tunguska Meteor in 1908 at about 300dB. Perhaps where planets or black holes collide, or where supernovae explode, there may be sounds more powerful than this.

PHOTOS: SCIENCE PHOTO LIBRARY, ISTOCK, PRESS ASSOCIATION

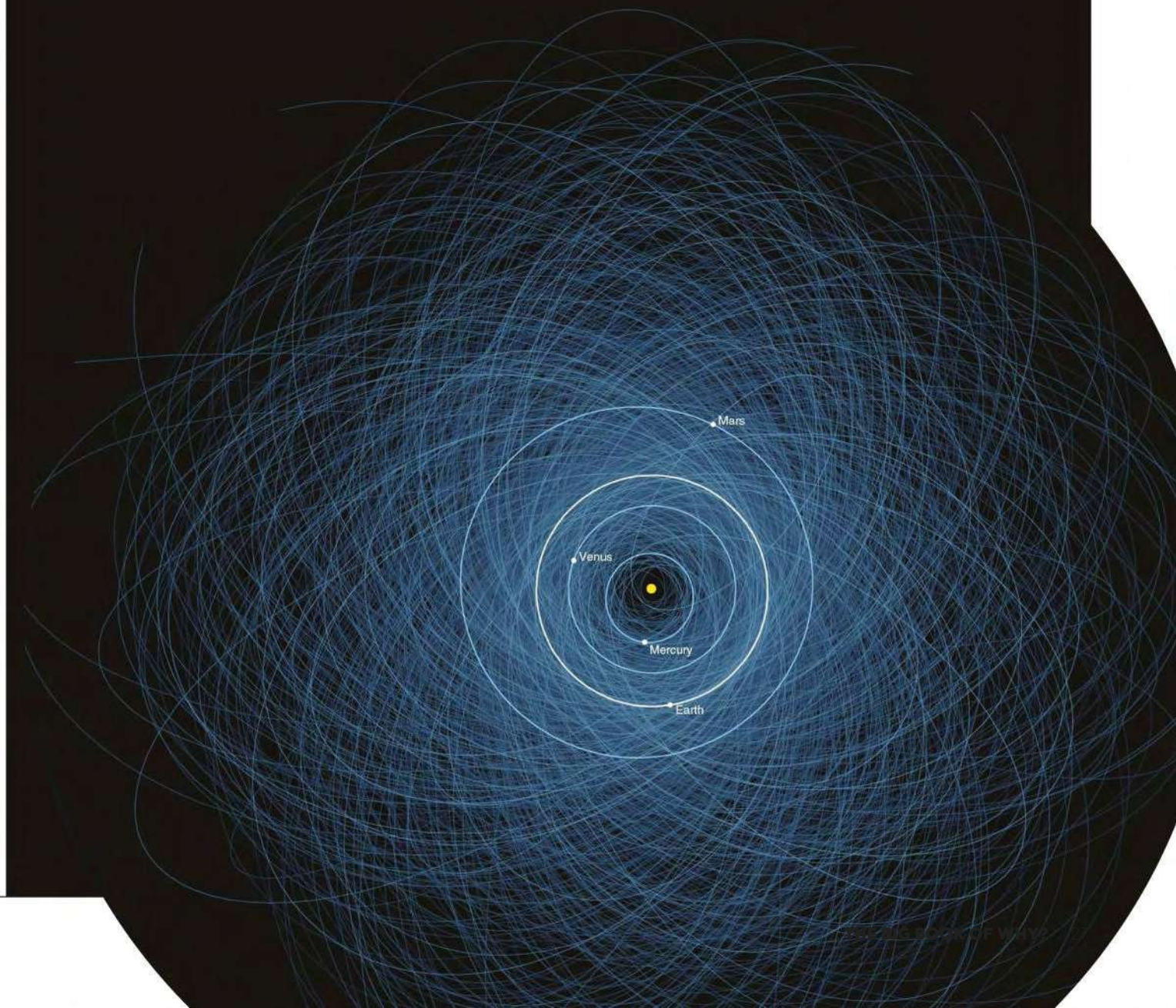
HOW MANY POTENTIALLY HAZARDOUS ASTEROIDS ARE THERE?

A potentially hazardous asteroid (PHA) is an asteroid whose orbit comes nearer than 0.05AU (about 7.5 million km) of Earth and whose brightness implies a size of the order of about 100m across or more. Such objects would have devastating consequences if they were to impact the Earth.

At the time of writing, the International Astronomical Union lists a total of 1,466 potential hazardous asteroids. This does not mean all these objects will eventually hit Earth – just that they have the potential to do so. Of course, this number represents only the PHAs we know about.

A recent survey by NASA's WISE satellite suggested there are at least 4,700 such objects.

Although we're in no immediate danger, asteroids big enough to cause major destruction, particularly in heavily populated areas, have hit Earth on average every 200 to 300 years.



PHOTOS: NASA/JPL

What's the most distant galaxy that's been seen?

Currently, the most distant (and hence oldest) galaxy known to astronomers is called z8_GND_5296. It was discovered in 2013 using a combination of data from the Hubble Space Telescope and the WM Keck Observatory in Hawaii.

Astronomers use a measurement called redshift to determine distance. This galaxy is an estimated 13.1 billion light-years away. This means we are seeing z8_GND_5296 as it was only 700 million years after the Big Bang.

Not only is z8_GND_5296 a record-holder, it is also an oddity. While normal galaxies like our own Milky Way may produce a couple of new stars each year, z8_GND_5296 has a star-formation rate 150 times greater.

HOW WOULD FIZZY DRINKS BEHAVE IN SPACE?

Without gravity, there is no density gradient within the drink, so its bubbles float around randomly inside the liquid. Occasionally a bubble strikes another with enough force to overcome the surface tension and they merge, so over time the bubbles coalesce into a few large bubbles that squash the others into a sort of static foam.

Why aren't planets overcome by the Sun's gravitational pull?

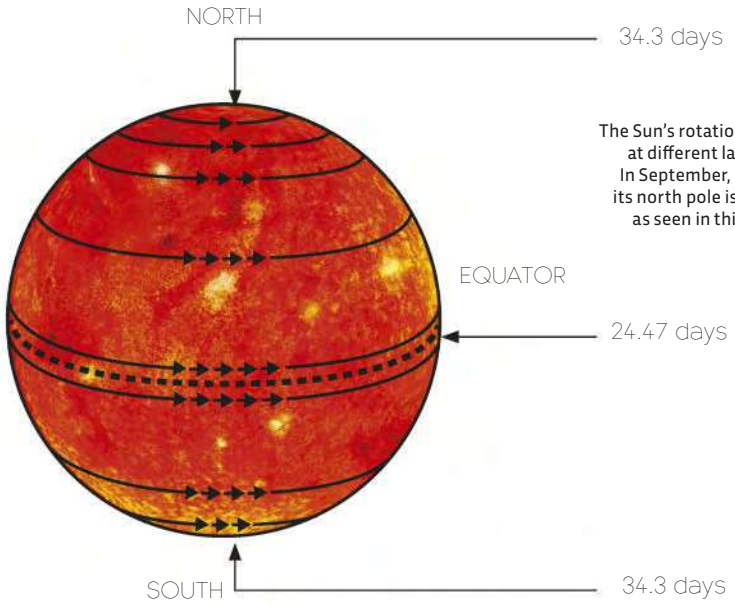
The planets don't crash into the Sun because they are moving too fast. Gravity pulls the planets towards the Sun, but the planets are also moving around the Sun. The sideways motion balances the force of attraction so that the planets don't move appreciably in the Sun's direction. In effect, the planets are constantly falling towards the Sun but always miss! Without the Sun's gravity to pull it 'down', Earth would career off into space. Or, putting it another way, if Earth stopped moving, it would crash into the Sun. You can create a similar effect by swinging a large spring with a weight attached to one end. If you swing it fast enough, the spring won't stretch, unless it goes faster. But if it slows down, the spring will pull the weight in.

PHOTOS: NASA, ISTOCK X2

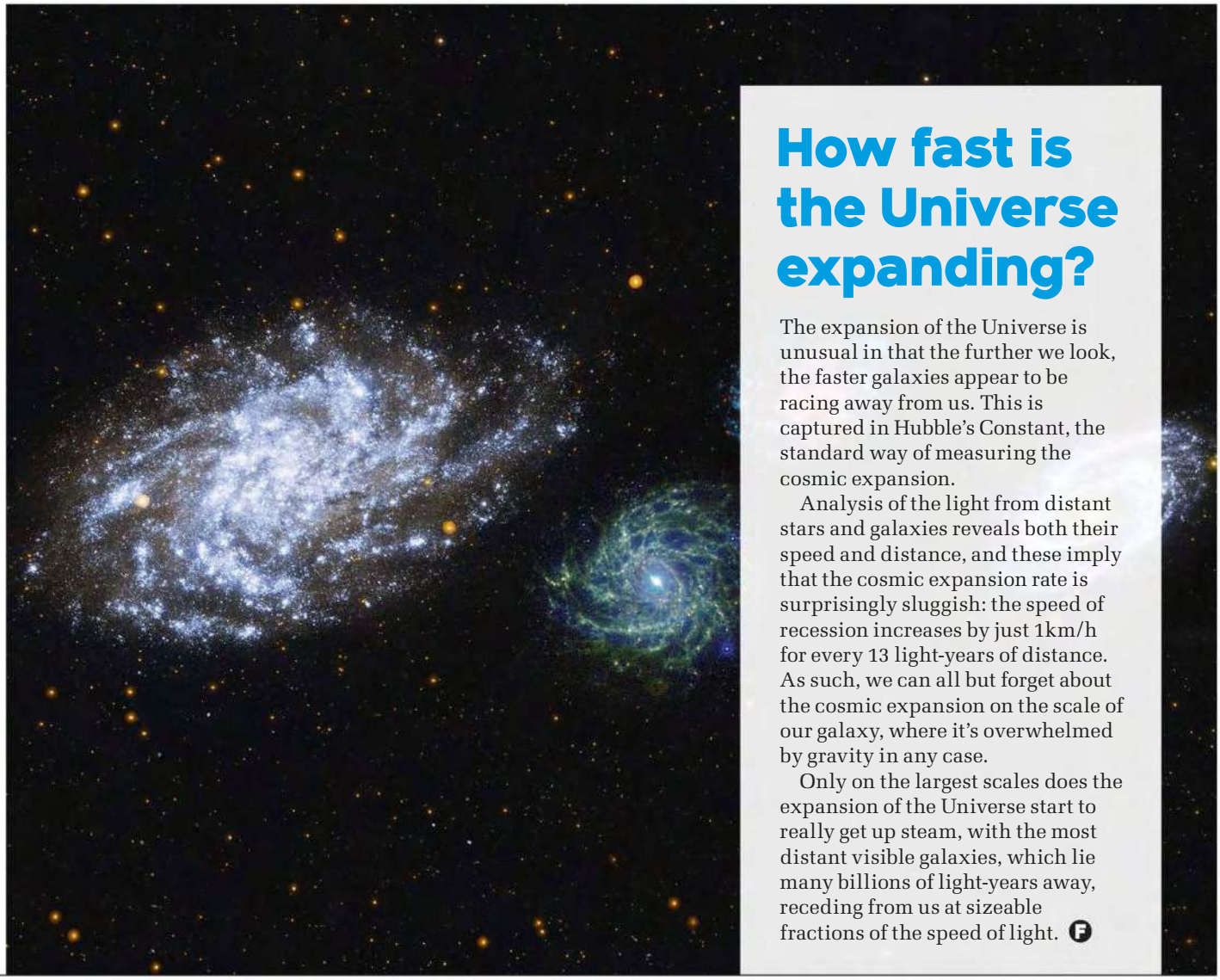
DOES THE SUN SPIN?

Yes, the Sun does spin, but not quite like Earth. It displays something called 'differential rotation', which means that some parts of it spin faster than others. The Sun spins once every 24.47 days at its equator, but only once every 34.3 days at its poles. Of course, since Earth is orbiting the Sun and moves relative to the solar rotation, these lengths appear slightly longer to us on Earth.

The Sun's rotations vary because it is gaseous, although its interior actually does rotate like a solid body. Astronomers often refer to the Sun's rotation period at 26° latitude, the typical latitude of sunspots. This period is 25.38 days, or 27.28 days measured from Earth. The Sun's differential rotation, combined with the convection of material within it, drives its magnetic cycle.



The Sun's rotation varies at different latitudes. In September, more of its north pole is visible, as seen in this image



How fast is the Universe expanding?

The expansion of the Universe is unusual in that the further we look, the faster galaxies appear to be racing away from us. This is captured in Hubble's Constant, the standard way of measuring the cosmic expansion.

Analysis of the light from distant stars and galaxies reveals both their speed and distance, and these imply that the cosmic expansion rate is surprisingly sluggish: the speed of recession increases by just 1km/h for every 13 light-years of distance. As such, we can all but forget about the cosmic expansion on the scale of our galaxy, where it's overwhelmed by gravity in any case.

Only on the largest scales does the expansion of the Universe start to really get up steam, with the most distant visible galaxies, which lie many billions of light-years away, receding from us at sizeable fractions of the speed of light.

PHOTOS: ISTOCK, NASA

OVER AND OUT

This giant hunk of gleaming ice is the underside of a recently overturned iceberg. When icebergs are irregularly shaped or melting, they can become imbalanced and flip over, releasing energies comparable to that of an atomic bomb.

"An iceberg will flip depending on its geometry as well as its density,' explains Justin Burton, Assistant Professor of Physics at Emory University, Atlanta. "If it is tall and skinny, it will tip over." While iceberg flips rarely occur, increases in temperature due to climate change are making it more common.

The newly exposed underbelly of the iceberg has not been sullied by snow, debris or weathering, so light can shine through it more easily, giving it a vibrant, aquamarine hue.

"The blue colour means it came from depth and was formed under pressure," says Burton. Bubbles and air pockets were pushed out of the ice, meaning that the light can travel further into the iceberg before scattering. "The further it travels, the more red it absorbs and the bluer it looks."

PHOTOGRAPHY: CORNELL

THE WORLD AROUND US

Computer games, whistling kettles, motion sickness, Facebook, railway tunnels, electric showers, fizzy drinks, online shopping...

Yes it does, especially if you put the phone and the rice into a sealed plastic bag. But while the rice will draw out the moisture, that doesn't necessarily mean your phone will work properly afterwards. The water may already have fused the phone's circuits or left behind traces of minerals that corrode the electronics. Also, rice may get stuck in the headphone socket. Soaking the phone in pure alcohol may be a better bet. The alcohol drives water out and removes any mineral deposits. But pure alcohol is highly flammable and must be treated with the utmost care.

DOES PUTTING A WET MOBILE PHONE IN RICE ACTUALLY DRY IT OUT?

DO VIDEO GAMES MAKE PEOPLE ANGRY?

We don't know for sure, even though the question is important for education and parenting. Many studies show that kids who regularly play violent games show more savage behaviour, but this is only a correlation and not a cause. It could be that aggressive children prefer violent games, not that the games caused their aggression.

In some studies, the victor of a video game has been given the opportunity to punish their opponent by blasting them with noise, for example. It has been found that winners of violent games are more likely to punish their opponent than winners of non-violent games. Violent games with a positive goal, such as saving others from virtual zombies, seem to have less negative impact.

Other research shows that losing the game or finding the controls frustrating is what leads to violence, not the content of the actual game itself.

We should also note that US sales of violent video games have steadily increased since the mid-1990s, while violent crime has declined – especially among juveniles.

WHAT IS DUST MADE OF?

It's not mostly human skin: that mainly ends up in the bath or shower. Two-thirds of the dust in your house comes from outside, as dirt tracked in on your feet, and airborne particles like pollen and soot. The rest is mostly carpet fluff, clothes fibres and pet hair.

Can the Sun shining through glass really cause house fires?

It may sound like an urban myth, but it can – and does – happen. Fish tanks, jam jars and even glass door knobs have been implicated in focusing the Sun's rays sufficiently to cause smouldering, followed by a full-scale blaze. London Fire Brigade have reported that 125 fires have been triggered by the Sun's rays over the last five years, while warning that the risk exists during the winter as well as summer. That's because the Sun's rays bathe Earth in a constant flow of thermal energy spread over each square metre. This energy is too dilute to ignite paper, wood or other combustible substances, but if the rays are focused, it becomes concentrated enough to exceed the threshold for combustion. Magnifying glasses do this very effectively, refracting the rays and bringing them to a tight focus. But even fragments of glass can have some focusing effect – with potentially disastrous consequences.

PHOTOS: ALAMY, GETTY X2, ISTOCK

Do plants really grow better if they 'hear' human voices or music?

There is some evidence that they might. A 2014 study from Osmania University in Hyderabad in India found that roses grew faster when exposed to Indian classical music than they did to Western rock music or silence. And a 2011 study at Zhejiang University in China reported 10 per cent faster mushroom growth when the fungi enjoyed a mixture of music and cricket chirps. Sound vibrations have also been shown to activate certain plant genes. But in these studies the researchers could hear the music too, so it may be that people do a better job of tending plants when they listen to music they like.

What are the small bubbles that form in a glass of water?

Water contains dissolved gases. When a glass of water is left to stand, the molecules come out of solution and accumulate around small imperfections on the glass. This process of 'nucleation' continues until a bubble forms, breaks free and rises to the surface. Dropping a lemon pip into fizzy water can trigger repeated cycles of nucleation and bubble formation, making it rise and fall repeatedly.

IS IT SAFER TO FACE BACKWARDS IN A PLANE?

There's a simple answer to this: yes. In the event of a hard landing or minor crash, a rear-facing seat spreads the deceleration forces better across the body. A US Air Force study in 1957 found that passengers were seven times more likely to survive a crash if they sat facing backwards. But rear-facing seats have different stresses and would need to be made stronger and heavier, improvements that would have an impact on aircraft efficiency.

PHOTOS: GETTY X2, ISTOCK

How are TV viewing figures calculated?

TV ratings are compiled daily by the Broadcasters' Audience Research Board. BARB recruits 12,000 people across 5,100 households, a selection representative of the overall UK viewing public. As well as demographics and geography, the panel is selected according to platform, whether that's a TV set, desktop computer, laptop or tablet. The devices log data about what members of the household are watching. BARB computers rush the figures out to the broadcasters within hours.

IN NUMBERS

49.8
million

The weight, in kilograms, of cigarette filters discarded every year by US smokers.

WHY DO SHIPS SINK IN THE BERMUDA TRIANGLE?

Ships sink in all parts of the ocean and there's nothing particularly dangerous about the seas around Bermuda. In fact, a 2013 study found that the most dangerous waters were the South China Sea, the Mediterranean and the North Sea. The Bermuda Triangle doesn't even make the top 10, despite being one of the world's busiest shipping lanes. There have actually been no sinkings in the Bermuda Triangle since 1967. Various theories, such as magnetic compass anomalies, have no evidence to support them.

TOP TEN

COUNTRIES WITH THE MOST FACEBOOK USERS

1. United States
Number of users: 152 million
Population: 319 million

2. India
Number of users: 109 million
Population: 1.3 billion

3. Brazil
Number of users: 71 million
Population: 200 million

4. Indonesia
Number of users: 60 million
Population: 250 million

5. Mexico
Number of users: 44 million
Population: 122 million

6. Philippines
Number of users: 34 million
Population: 98 million

7. Turkey
Number of users: 32 million
Population: 75 million

8. United Kingdom
Number of users: 30 million
Population: 64 million

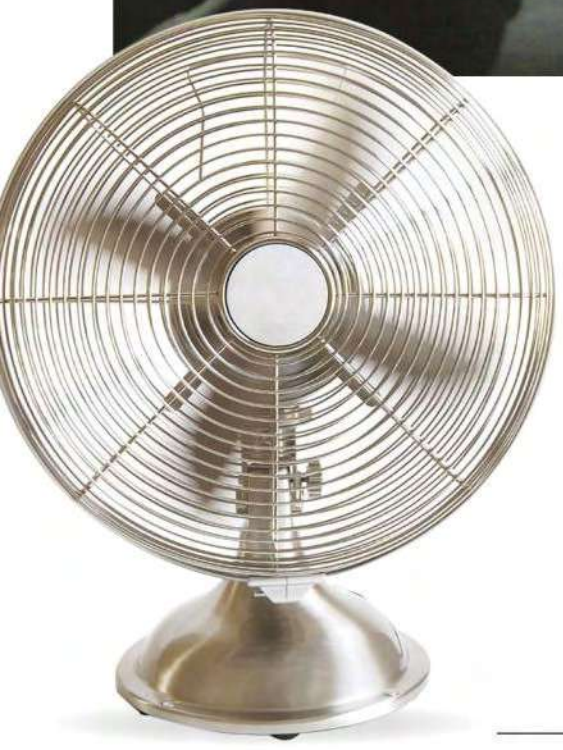
9. Japan
Number of users: 27 million
Population: 127 million

10. France
Number of users: 23 million
Population: 66 million

PHOTOS: GETTY, ALAMY

WHAT'S THE LONGEST RAILWAY TUNNEL IN THE WORLD?

Line 3 of the Guangzhou Metro in China has a main branch line that is 60.4km (37.5 miles) long. But if you discount urban metro lines, the title goes to the Seikan Tunnel in Japan, which connects the islands of Hokkaido and Honshu. This is 53.85km (33.5 miles) long and is also the deepest rail tunnel in the world, running 100m below the seabed. This record will be beaten in June 2016 when the 57.1km (35.5-mile) Gotthard Base Tunnel through the Swiss Alps is due to open. But both of these tunnels will be eclipsed by the 123km (76.4-mile) Bohai Strait Tunnel, which is planned to connect the Chinese cities of Dalian and Yantai by 2023.



How do fans make you feel cooler?

As long as the air blowing past your face is cooler than your skin, some heat will transfer to the air molecules. The fan ensures those molecules are moved out of the way before they have a chance to reach the same temperature as your face and replaces them with other molecules that haven't yet been warmed. Similarly, sweating transfers heat to the evaporated water molecules, and the fan prevents a humid layer from building up next to your skin that would slow down the rate of evaporation.

DID YOU KNOW?

The lift with the largest passenger capacity is situated in Osaka's Umeda Hankyu building. It holds 80 passengers.

PHOTOS: GETTY, ISTOCK

WHICH IS BETTER FOR YOU – COLA OR DIET COLA?

The main difference is obviously that cola contains sugar and diet cola contains artificial sweetener. In the UK, that sweetener is aspartame and the current scientific consensus is that this additive is safe at the concentrations found in diet drinks. The 35g of sugar – around seven teaspoons – in a can of Coca-Cola, on the other hand, contains 139 calories, which will contribute to obesity and tooth decay. It can also lead to Type 2 diabetes if you drink too much of it. On balance, diet cola is probably the least bad but neither is actually good for you.

IN NUMBERS

221

The average amount of times that a British smartphone user checks their device each day, according to a study commissioned by Tecmark.

Are there any games at which people can still beat computers?

Humans still have the edge in the game of Go. Like chess, it's played on a chequered board, but the board has more squares (19x19) and each piece can perform many more potential moves. While chess becomes more computationally straightforward as the game progresses and pieces are removed, Go requires more judgment and intuition. These attributes are more suitable to human intelligence than machine algorithms.

WHAT'S THE BEST WAY TO BRUSH YOUR TEETH?

A recent study by Prof Aubrey Sheiham and colleagues at University College London found an "unacceptably inconsistent array of advice" from dental associations, dentists and toothbrush companies. Some dentists claim a side-to-side motion is fine, while others insist on different actions in different parts of the mouth. Sheiham himself recommends brushing from side to side, with the brush at a 45-degree angle and held lightly. He also suggests focusing on where plaque is most likely to collect, which is biting surfaces and where teeth meet gums.

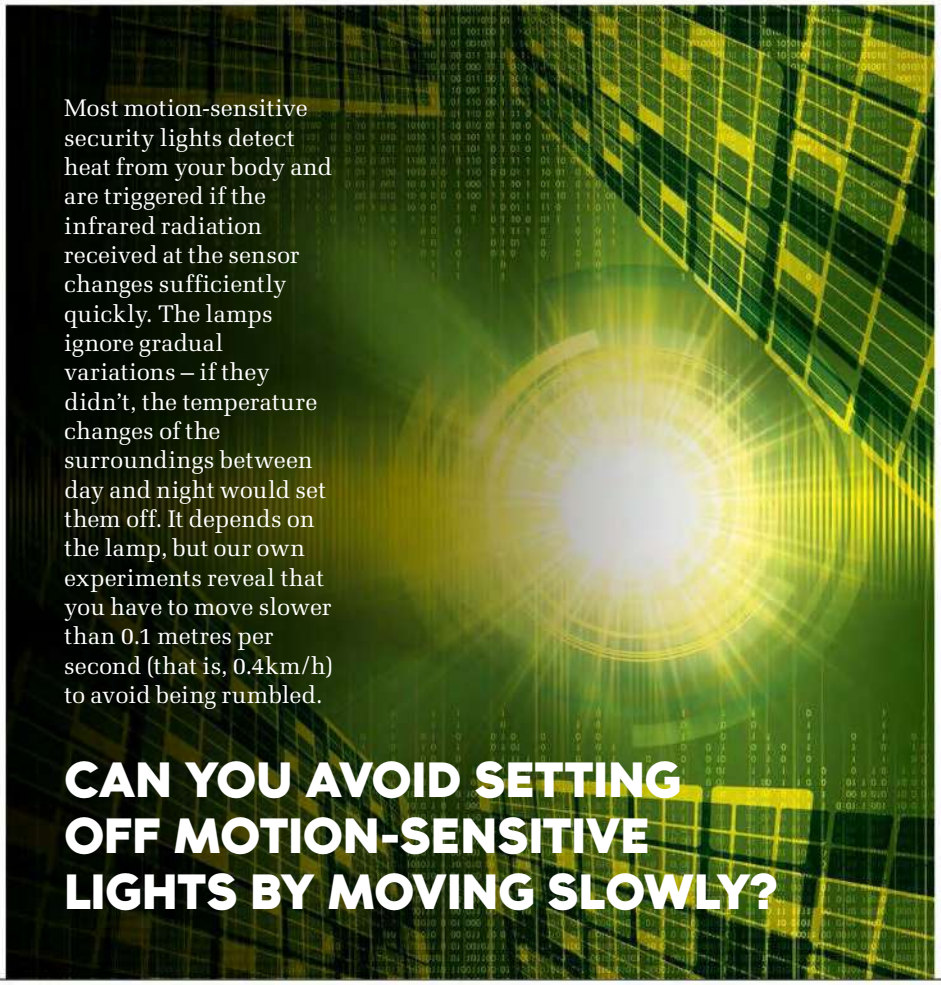
PHOTOS: ALAMY, ISTOCK X2

How do electric showers heat water so quickly?

Inside the shower unit, cold water from your mains supply flows into a small plastic tank. Inside the tank is a heating element similar to the one found in a kettle but, at around 11kW, four times more powerful. The water heats up almost instantly because only enough to maintain the flow is warmed at a time. There is also a safety cut-out should the water pressure fall too low.

Why does tape 'screech' when you peel it off?

Scientists have been investigating the source of this appalling noise since the 1990s and have been amazed by the complexity of the phenomenon. Put simply, it's caused when the tape is peeled off at a speed and angle that causes the glue to intermittently stick then slip, creating jagged, unpleasant sound waves.



Most motion-sensitive security lights detect heat from your body and are triggered if the infrared radiation received at the sensor changes sufficiently quickly. The lamps ignore gradual variations – if they didn't, the temperature changes of the surroundings between day and night would set them off. It depends on the lamp, but our own experiments reveal that you have to move slower than 0.1 metres per second (that is, 0.4km/h) to avoid being rumbled.

CAN YOU AVOID SETTING OFF MOTION-SENSITIVE LIGHTS BY MOVING SLOWLY?

PHOTOS: ISTOCK X5, GETTY

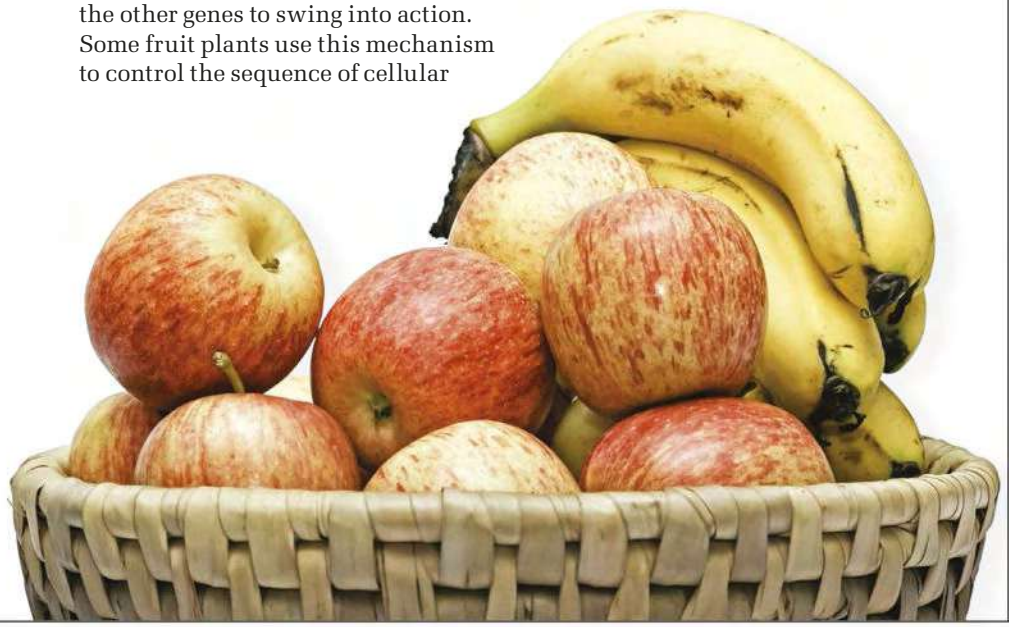
WHICH COUNTRIES SHOP ONLINE THE MOST?

At number one is the UK, with 60 per cent of adults shopping online, spending just over £68bn. This is according the most up-to-date figures from the Organisation for Economic Co-operation and Development (OECD).

The UK figure is actually double the OECD average and is followed by Denmark, where 53 per cent of people shop online. Germany and France are at 48 and 42 per cent respectively.

Why do bananas make fruit ripen faster?

Bananas produce ethylene gas (C_2H_4), which acts as a plant hormone. Plants have genes called ETR1 and CTR1 that regulate lots of other genes involved with growth, ageing and cell death. When ethylene gas is present, ETR1 and CTR1 are shut off, which allows the other genes to swing into action. Some fruit plants use this mechanism to control the sequence of cellular changes in their ripening process. Bananas actually only produce moderate levels of ethylene but apples, pears and melons are so sensitive to the hormone that it has a powerful effect on their ripening.



Why do different countries use different mains voltages?

The biggest disparity is between the US (on 110V) and most of the rest of the world (on 230V). The US voltage goes all the way back to Thomas Edison, who introduced direct current (DC) mains electricity at 110V. Edison's rival Nikola Tesla showed that long power lines transmitted alternating current (AC) more efficiently than DC. His AC approach won out, but he stuck with Edison's 110V. It's been that way in the US, Canada and parts of the Caribbean ever since. But by the time electrification spread to Europe in the early 20th Century, lamps had filaments that gave out more light and handled greater power loads. So the German Berliner Elektrizitätswerke company established 230V as the standard.

How fast does electricity flow?

Drift velocity, the average speed at which electrons travel in a conductor when subjected to an electric field, is about 1mm per second. It's the electromagnetic wave rippling through the electrons that propagates at close to the speed of light. The dimensions of the wire and electrical properties like its inductance affect the exact propagation speed, but usually it will be around 90 per cent of the speed of light – about 270,000 km/s.

IN NUMBERS

36

The number of days a year that are spent answering work emails by the average British employee.

HOW DOES A WHISTLING KETTLE WHISTLE?

Most kettle whistles consist of two parallel metal plates with a hole running through them through which steam passes. The whistling sound is the result of this flow of steam making the air vibrate rapidly, but only now have researchers worked out how.

According to Ross Henrywood and Dr Anurag Agarwal at the University of Cambridge, there are two mechanisms at work. The first, known as Helmholtz resonance, occurs when the steam tries to push out of the whistle, only to run into the natural 'springiness' of air still in it. The resulting vibrations produce the first sounds from the whistle. But as the steam gets hotter, it pushes through the holes in the whistle faster, creating ripples of turbulence, and these generate the final note.

Can you walk across slippery surfaces without falling?

Research at California's Salk Institute for Biological Sciences found that we balance on slippery or narrow surfaces using clusters of RORa neurones in the spinal cord. These 'mini brains' process the sensory information from your skin, muscles, inner ear and eyes and make hundreds of tiny corrections per second.

You can reduce your chances of a fall by copying penguins. Your centre of gravity is normally directly above the weight-bearing foot for just a small part of each stride. If you waddle from side to side instead, your centre of gravity stays above one foot or the other, making it less likely your foot will suddenly slip.

How do bath bombs work?

The part that makes them fizz is the same as an Alka Seltzer or soluble aspirin tablet: sodium bicarbonate and citric acid. In water, these chemicals dissolve and react with each other to form sodium citrate and carbon dioxide. The sodium citrate stays in solution and you don't really notice it, but the carbon dioxide bubbles out as a gas that helps the bath bomb break up. This lets the detergents, perfumes and oils that make up the rest of the bath bomb mix with the bathwater.

DID YOU KNOW?

Made in June 2012 in Poland, the largest-ever lasagne weighed 4,865kg and was divided into 10,000 portions.

Why don't some people get motion sickness?

No-one is entirely immune to motion sickness, but some are definitely more susceptible than others. A study by Pennsylvania State University found that 80 per cent of Asians suffered from motion sickness but less than 50 per cent of African-Americans or Caucasian-Americans. So it's probably genetic. It could also be related to your taste sensitivity. People who are more sensitive to bitter compounds are more likely to get motion sickness.

Are my files safe if I store them in the cloud?

No file is 100 per cent safe, whether in the cloud or on your desktop. In the cloud, your files could be hacked, intercepted or lost. Even if the cloud service provider is watertight, there's always the danger that someone might be eavesdropping on your web connection when you access your files, or stealing your password with a key logger.

Cloud services that have built their businesses on securing, encrypting and storing data are probably more trustworthy. But before signing up to any service, check its data protection and privacy policies. Most cloud providers forbid their staff from accessing user content directly, but they may look at metadata, such as file names, dates created or location. Also, your files may be stored in jurisdictions that require your provider to decrypt files for law enforcement. If that bothers you, best to stay out of the cloud and just be careful with your own machine.

Is it best to charge your mobile from empty or half full?

Nickel-based batteries were blighted by the 'memory effect' and would lose capacity unless discharged completely on a regular basis. Most phones nowadays have lithium batteries, and these do not suffer from the memory effect. In fact, it is good for them if you top the batteries up rather than deplete them completely. Therefore, it's best to charge your phone from half full.

PHOTOS: ISTOCK XS, ALAMY, GETTY

WINGED WONDERS

With their 50cm wingspans, these are not your typical insects. They are eMotionButterflies, one of the latest creations of German automation company Festo.

Their ultra-light wings are made from carbon rods, covered by a film of blue elastic. Each body includes one battery and two small motors, allowing four minutes of flight between charges.

Infrared cameras track the robots by detecting the position of tiny LEDs attached to each butterfly's body. A central computer monitors these positions, instantaneously updating the butterflies' routes to keep them out of harm's way.

"Nature shows us that even animals that are neither strong nor particularly complex can demonstrate coordinated movement as a collective," says Festo's Dr Heinrich Frontzek. "This does not require intricate programming, but only a limited number of simple rules for avoiding collisions."

According to Festo, the technology in these bots could be used in a "guidance and monitoring system in the factory of the future".

PHOTO: FESTO


FESTO

ENERGY AND ENVIRONMENT

Disposable nappies, the ozone layer, relocating polar bears, traffic noise, acid rain, paper production, melting glaciers, endangered countries...

WHAT WOULD HAPPEN IF ALL THE GLACIERS MELTED?

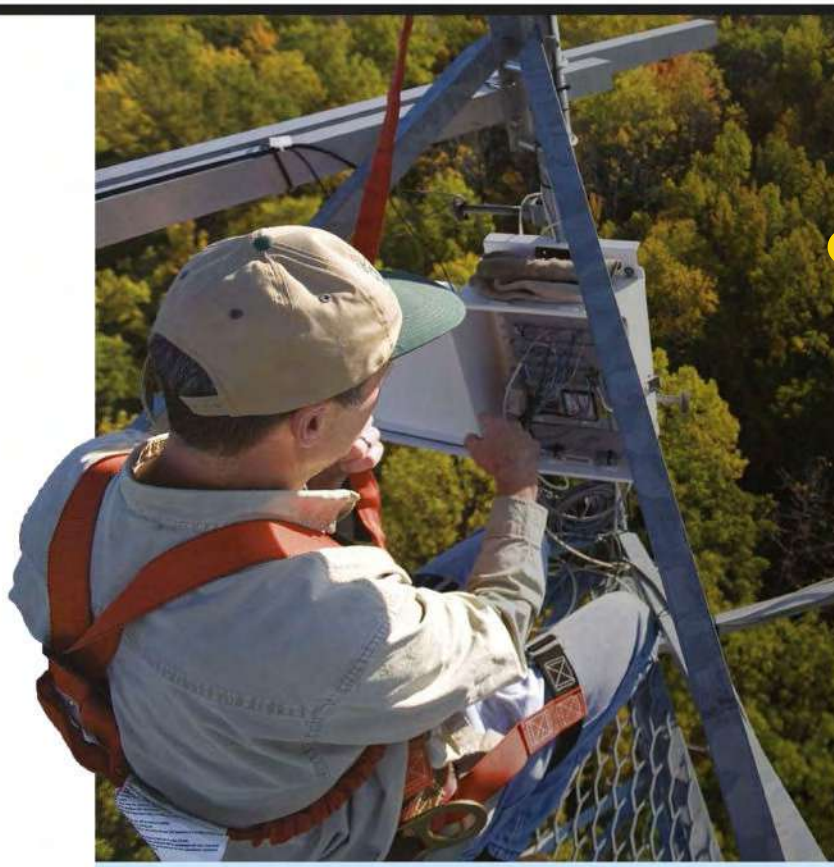
Despite the effects of continuing global warming, a tenth of the planet's land mass is still covered in ice (compared with 32 per cent at the time of the last Ice Age). Glaciers form a large proportion of this frozen landscape and store around three-quarters of Earth's reserves of fresh water.

If global warming ever became so extreme that all the glaciers melted, sea levels would rise by a beyond-catastrophic 70 metres.

IN NUMBERS

560 BILLION

The number of tonnes estimated to represent the total biomass of animals and plants on Earth (excluding bacteria).



Have we made any difference to climate change yet?

Quite possibly – but not in a good way. The principal drivers of climate change are greenhouse gases that trap the Sun's heat. The most important of these is carbon dioxide (CO_2), produced by human activities such as energy generation and transportation. The good news is that 2014 saw CO_2 emissions from the energy sector remain static, suggesting the message about fossil fuels is finally getting through. However, in May 2015, the total amount of atmospheric CO_2 exceeded the highest level since measurements began in 1958.

Perhaps most concerning of all is the fact that even if emissions of all greenhouse gases ceased entirely tomorrow, any warming would still persist for many centuries. That's partly because CO_2 lingers in the atmosphere for several centuries after release, and partly because the oceans are sluggish to react to any cooling.

COULD TRAFFIC NOISE BE CONVERTED TO USEFUL ENERGY?

While it might sound deafening, traffic noise is actually a feeble source of energy. Even the 100dB roar of a lorry passing by generates barely a hundredth of a watt of power per square metre. By way of comparison, sunlight is tens of thousands of times more concentrated.

Do trees have to be used to produce paper?

No. In fact, more eco-friendly materials are increasingly used for paper production, including bamboo, banana husks and hemp (which was actually the main source of paper in the 19th Century). More esoteric alternatives include 'rock paper' made from ground-up minerals and a non-toxic chemical binder, which also needs less ink for printing.

PHOTOS: GETTY, SCIENCE PHOTO LIBRARY, ISTOCK X2

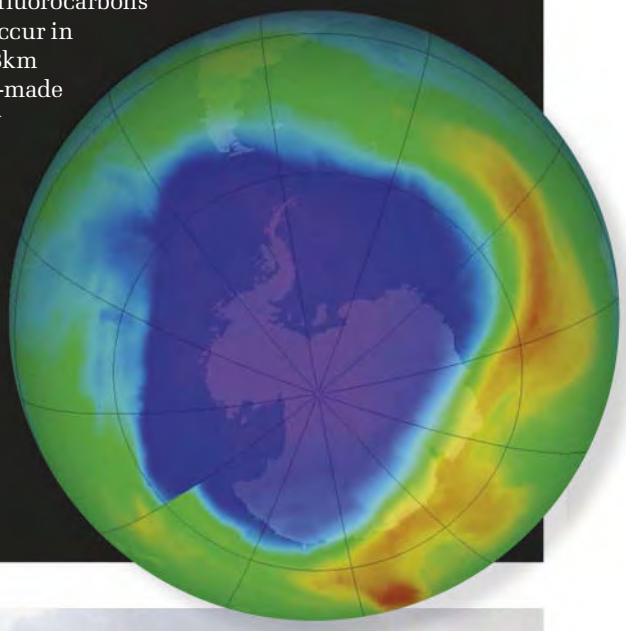
DID YOU KNOW?

The most densely populated city in the world is Dhaka in Bangladesh. There are 44,500 people in every square kilometre.

WHY IS THE HOLE IN THE OZONE LAYER OVER ANTARCTICA IF IT'S UNINHABITED?

Ozone depletion is mainly caused by chemical reactions between compounds such as chlorofluorocarbons (CFCs) and ultraviolet light. These occur in the stratosphere, at altitudes above 8km (5 miles). By the time polluting man-made CFCs get that high, they have evenly dispersed around the globe, so whether or not people live and work under the ozone hole isn't the determining factor in its location.

The reason that the hole forms above Antarctica is because the ozone-destroying reactions happen much faster on the surface of the tiny ice crystals found in a type of cloud, called polar stratospheric cloud, which forms in the cold, dry conditions of the Antarctic.



With the current rate of pollution, when will Earth become uninhabitable for humans?

It won't. Humans are not like yeast, which continues to metabolise in an uncontrolled manner until it is poisoned by its own waste products. As human pollution levels rise, the political imperative for us to do something about it increases as well. The Great Smog of London in 1952, which killed 4,000 people, was followed four years later by the Clean Air Act. Similar legislation in the US has seen the overall emissions of air pollutants fall by about 60 per cent in the last 35 years. The US 1990 Oil Pollution Act required oil tankers to have double hulls to reduce the risk of spills. The 1987 Montreal Protocol eliminated almost all CFCs from industrial and consumer products worldwide. Leaded petrol and the pesticide DDT are also banned in most places. Air and water pollution are still a major problem in newly industrialised regions, particularly China, India and South America. But even then, pollution is rising more slowly than when the West went through the Industrial Revolution. This is because of better awareness and technology, as well as pressure from the rest of the world.

Global population is expected to peak around 10 or 11 billion. With care, it's possible that we may be able to sustain a habitable planet for that many humans more or less indefinitely. We may still become extinct through climate change, disease, nuclear war or meteorite impact, but humanity probably has enough foresight and resources to avoid poisoning itself to death.

PHOTOS: ISTOCK, SCIENCE PHOTO LIBRARY, PRESS ASSOCIATION

ARE DISPOSABLE NAPPIES MORE HARMFUL TO THE ENVIRONMENT THAN REUSABLE ONES?

Mostly. Eight million disposables nappies end up in UK landfill sites every day. We don't know exactly how long they take to biodegrade, but it's likely to be more than 100 years. This means every nappy that's ever been thrown away is still there, and potentially leaking nasty chemicals into the groundwater. But if you compare the carbon footprint of manufacturing disposables with the energy used to manufacture and launder reusable ones, the picture is less clear. A 2008 study by the Environment Agency concluded that washable nappies are actually responsible for 3 per cent higher CO_2 emissions than disposables, per child.

But these figures assume that 25 per cent of washable nappies will be dried in a tumble drier. If you dry all your nappies on the line, the balance switches and reusable nappies produce 13 per cent less CO_2 emissions than disposables.

PHOTOS: GETTY X11

TOP TEN

CLIMATE CHANGE-AFFLICTED COUNTRIES

1. Honduras
Droughts and floods hit food production.

2. Myanmar
Warmer temperatures have led to huge increases in the spread of water-borne diseases.

3. Haiti
The number and power of hurricanes have increased significantly in recent years.

4. Nicaragua
Two category-5 storms in the past 15 years claimed thousands of lives.

5. Bangladesh
Frequent flooding of the Ganges delta wipes out crops, destroys homes and spreads diseases.

6. Vietnam
Increases in flash floods, landslides and other natural disasters have caused many deaths.

7. Philippines
Increasingly frequent, intense natural disasters claim thousands of lives.

8. Dominican Republic
Flooding and erosion are both causing major problems for the Caribbean country.

9. Mongolia
In the past 70 years, average temperatures have increased by 2°C and rainfall has decreased, hitting agriculture particularly hard.

10. Thailand
Crops have been increasingly destroyed by floods.

As determined by the German Watch Long-Term Climate Risk Index

HOW DO WE KNOW HOW FAST SEA LEVELS ARE RISING?

Rising sea levels is one of the most worrying consequences of global warming, threatening more than 100 million people living in vulnerable coastal areas. But measuring the rate of the rise is fraught with difficulty. For more than 150 years, scientists relied on so-called tide gauges, which monitored the rise and fall of floats in tubes. However, such gauges proved vulnerable to errors – not least the rise and fall of the land. Satellite measurements based on radar are now used, but these too suffer from subtle errors caused by orbital, instrumental and atmospheric variability.

The need for precision is vital as the expected change in global sea levels is no more than a few millimetres a year. In 2005, the journal *Nature Climate Change* published the latest attempt to iron out the problems and the report suggests that Earth's oceans are rising by around 2.8mm per year. While this might not sound much, it's enough to prove a serious threat over the next 100 years.

IN NUMBERS

25%

The proportion of electrical and electronic equipment taken to UK waste depots that could actually be reused.

PHOTOS: ISTOCK

SHOULD WE MOVE POLAR BEARS TO ANTARCTICA TO PREVENT THEIR EXTINCTION?

This would just swap one disaster for another. In Antarctica, orcas and leopard seals hunt in the water. None of the other seals and penguins that live there have evolved any defensive behaviours while they are on the ice. If polar bears were suddenly introduced, there would be a brief population boom, followed by a crash, as the local seals and penguins were hunted to extinction. Even though the sea ice in Antarctica is currently growing, climate change is likely to affect the region in ways that will probably be just as bad for polar bears as the shrinking sea ice in the Arctic.

DID YOU KNOW?

The world's largest battery provides 36 megawatt hours of energy storage. It's housed in a huge building in Zhangbei, China, and stores energy from wind turbines and solar cells.

Whatever happened to the problem of 'acid rain'?

During the 1970s, acid rain emerged as a major environmental issue. Scandinavian nations blamed the UK's power stations for creating sulphur dioxide and nitrogen-based airborne pollution that spread across the North Sea to mix with rain, causing acid damage to forests and lakes. the UK itself was affected, with a 1980 report highlighting contamination to lakes and rivers. During the 1980s and 1990s, political pressure led to the introduction of international laws constraining the generation of the culprit compounds. Combined with wider use of cleaner forms of energy and improved standards of energy conservation, these measures led to substantial reduction in acid rain. In the US, the 1990 Acid Rain Program cut power station emissions of sulphur dioxide and oxides of nitrogen by over 70 per cent. The threat from acid rain is not the ecological threat it once was. F

PHOTOS: ROBERT HARDING, GETTY

SPRUCE ON THE LOOSE

Each spring, tendrils of brightly coloured spruce pollen swirl over the surface of Bavaria's Lake Sternberg. Unlike flowering plants, which are typically pollinated by insects, spruce trees rely on random wind currents to disperse their pollen. Obviously, this is a much less precise process, which means that vast quantities must be produced in order to enable successful reproduction. As a result, much of the pollen ends up going astray, creating large deposits of thick yellow dust as seen here.

"Pollen from spruce and pine keep their structure in water, whereas other pollen bursts," says Christian Bergmann from the German Pollen Information Service. "Large quantities are released when conditions are sunny, dry and a bit windy. Every year, you often see pine and spruce pollen in the water – even in the Baltic Sea."

PHOTO: PRESS ASSOCIATION

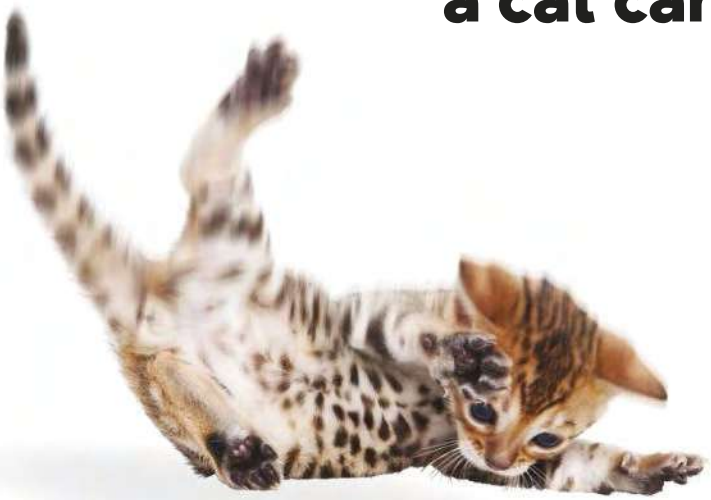
ANIMALS

Biggest spiders, smallest sharks, bat sonar, tiger stripes, penguin vision, longest-living mammals, the flight of butterflies, vultures' stomachs...

WHICH FISH CAN JUMP HIGHEST OUT OF WATER?

The Atlantic salmon (*Salmo salar)* can jump up waterfalls 3.7m high but, in open water the highest jumpers are all much larger fish. Some rays and marlin can leap three metres out of the water, but both are beaten by the shortfin mako (*Isurus oxyrinchus*). This acrobatic shark has been observed making jumps as high as six metres!

What is the maximum height that a cat can fall from and survive?



When a cat falls, it reflexively twists its body in mid-air so that its feet face downwards. There is a documented case of a cat falling from the 32nd storey of a New York skyscraper and surviving. But landing unscathed is far from guaranteed. A study in the *Journal Of The American Veterinary Medical Association* looked at 132 cats that had fallen an average of 5.5 storeys and survived, and found a third of them would have died without emergency veterinary treatment. Interestingly, injuries were worse in falls less than seven storeys than in higher tumbles. The researchers think that this is because they reach their terminal velocity after falling about seven storeys (21m), which means they stop accelerating. They then relax, allowing better distribution of impact.

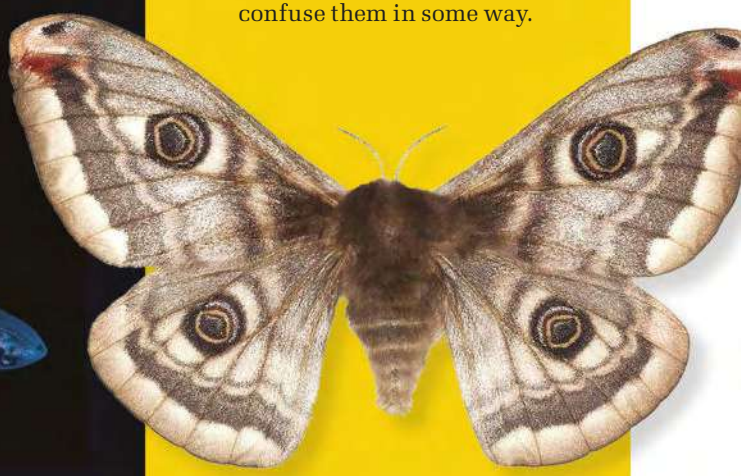
What is the smallest shark and what does it eat?

There are several candidates among the dogfish sharks, but the smallest is probably the dwarf lantern shark (*Etmopterus perryi*), which is about 21cm long.

The dwarf lantern shark lives off the coasts of Colombia and Venezuela. Light-emitting organs on its belly attract its prey, which includes small fish and shrimps.

WHY DON'T MOTHS FLY TOWARDS THE SUN?

Most moths are nocturnal, so during the day they keep still to avoid detection from predators. Moths don't fly towards the Moon, either; the idea that moths are trying to navigate by the Moon has been disproved. Exactly why moths fly towards artificial lights still isn't understood. All we know is that artificial lights confuse them in some way.



PHOTOS: OCTAVIO ABURTO, ISTOCK X4, SEAPICS.COM

Why do tigers have stripes?

When it comes to predatory adaptations, you wouldn't expect a colouration of bright orange with black stripes to be top of the list – in fact, it might not be on the list at all. However, while we typically see tigers in zoos, conspicuous against the green vegetation in their enclosures, their main prey is ungulates, which cannot detect the range of colours that we primates can. To an animal with comparatively poor vision, the cat's bold, contrasting colours are much harder to pick out in the long grass. This method of camouflage is an important predatory adaptation. Whereas some large felines rely on co-operative hunting (such as lions) or bursts of intense speed (such as cheetahs), tigers are semi-solitary and depend on their cryptic appearance to ambush prey.

DID YOU KNOW?

Cracker butterflies are the noisiest butterflies in the world. Their cracking forewings can be heard from 30m away.

Why do dogs and cats enjoy being stroked?

Stroking a cat or a dog causes the hormone oxytocin to be released in both the owner and the animal, which lowers blood pressure and reduces anxiety. It also promotes a feeling of wellbeing in humans, so it's assumed that animals experience a similar feeling too. But why has such a response evolved? One theory is that the domestication of animals originally offered a huge survival advantage to both humans and their pets. Humans selected the friendliest offspring from each litter, so each generation of animals grew more responsive to human contact. Plus, animal-loving early humans took advantage of guard dogs and pest-exterminating cats. Over time, humans and animals have co-evolved to enjoy each other's company.

HOW DO PENGUINS SEE CLEARLY UNDERWATER?

First, we need to understand a little about our own eyes. In humans, the cornea – the clear surface at the front of the eye – does most of the focusing. The lens only contributes about 10 per cent and fine-tunes the focus for sharp images at different distances.

Next, we need to look at light. All substances have a refractive index, which refers to the speed at which light travels through them compared to through a vacuum. When we're underwater, the refractive index of the water is too similar to that of our corneas. This means we can't focus as well and our lenses can't adjust enough to make up the difference. Therefore, our vision is blurry underwater unless we wear goggles. Goggles solve the problem because they introduce a pocket of air between the water and our eyes.

Penguins need to be able to see clearly both on land and in water. They have corneas that are much flatter than ours; this takes almost all of the focusing power away from the cornea, so the lens does most of the focusing. To form a sharp image, a penguin's eye must be able to vastly change the shape of the lens. Penguins' lenses are softer than ours and the muscles can squeeze them up against the opening of the pupil to help them focus in the water. Diving birds also use a similar technique when hunting underwater.

DID YOU KNOW?

The blue whale has the largest heart of any animal. It's roughly the size of a Volkswagen Beetle!

PHOTOS: FLPA, ISTOCK X2, GETTY

TOP TEN

BIGGEST SPIDERS

THE WORLD'S MOST AMPLE ARACHNIDS

1. Giant Huntsman
Length: Up to 30cm
Distribution: Caves in Laos. Other huntsman species are found worldwide

2. Goliath Birdeater
Length: Up to 28cm
Distribution: Upland rainforest regions of northern South America

3. Brazilian Giant Tawny Red
Length: Up to 26cm
Distribution: Tropical South America

4. Brazilian Salmon Pink Birdeater
Length: Up to 25cm
Distribution: Atlantic Forest, Brazil

5. Purple Bloom Birdeater
Length: Up to 22cm
Distribution: Moist forest areas of Colombia

6. Poecilotheria rajaei
Length: Up to 20cm
Distribution: Sri Lanka and parts of India

7. King Baboon Spider
Length: Up to 20cm
Distribution: East Africa, especially Kenya and Tanzania

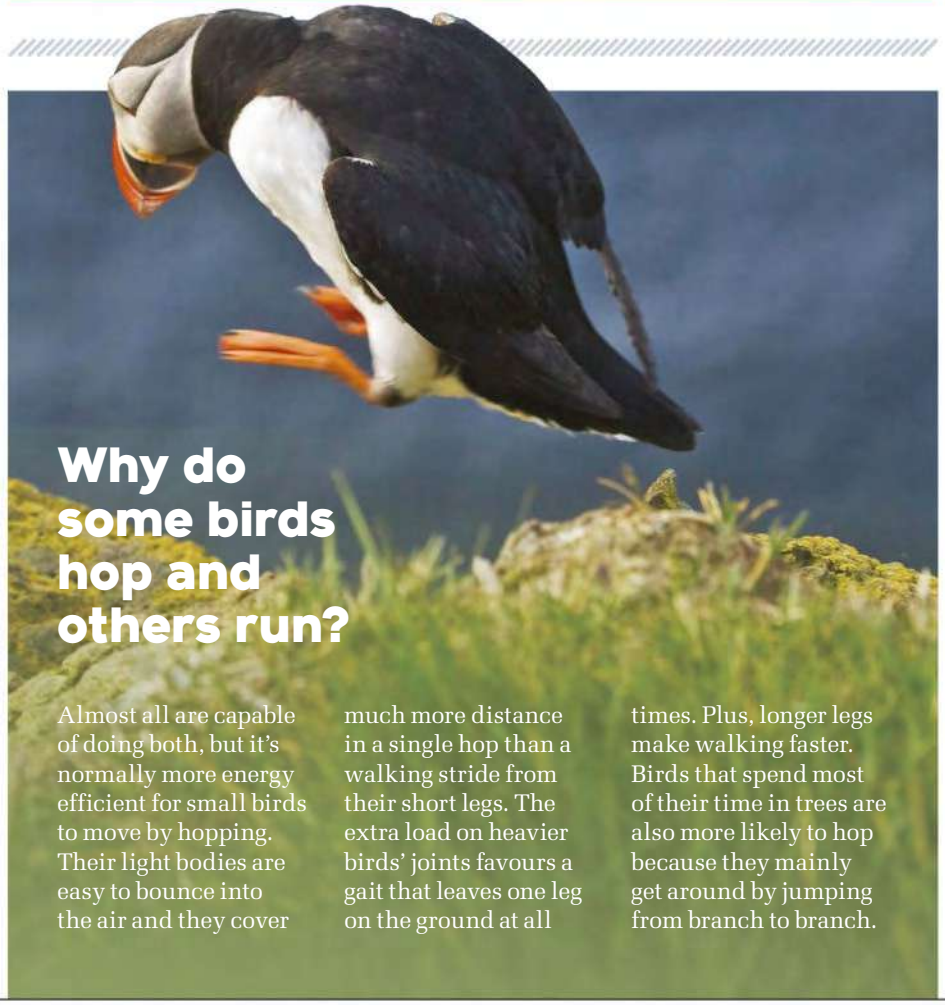
8. Golden Silk Orb-weavers
Length: Up to 16cm
Distribution: Australia, Asia, Africa and the Americas

9. Brazilian Wandering Spider
Length: Up to 15cm
Distribution: Forests of Central and South America

10. Cerbalus aravensis
Length: Up to 14cm
Distribution: Sand dunes in Israel and Jordan

Which mammal lives longest?

It's probably the bowhead whale – some individuals are thought to have lived beyond 200 years. The evidence comes from both research into the species' eye tissue (ocular amino acids increase over time) and discoveries of ivory spear tips and stone harpoon heads lodged in the blubber of those harvested by Eskimo whalers. Scientists theorise that the species' longevity is down to its low body temperature, which is thought to delay the ageing process. Most whales have a lifespan of 60 to 90 years.



Why do some birds hop and others run?

Almost all are capable of doing both, but it's normally more energy efficient for small birds to move by hopping. Their light bodies are easy to bounce into the air and they cover much more distance in a single hop than a walking stride from their short legs. The extra load on heavier birds' joints favours a gait that leaves one leg on the ground at all times. Plus, longer legs make walking faster. Birds that spend most of their time in trees are also more likely to hop because they mainly get around by jumping from branch to branch.

PHOTOS: MICKEY SAMUNI-BLANK/WIKI, RANIL NANAYAKKARA/FLICKR, PETRA & WILFRIED/FLICKR, JOSE LUIS BARTHELD, ANDREAS KAY, VLADEB/FLICKR, J&T REPTILES, STEVE SMITH/FLICKR, TJ PETROWSKI/FLICKR, ISTOCK

DO BIRDS FLY THROUGH CLOUDS?

Most birds fly no more than 150m off the ground and so won't find themselves inside clouds unless it's foggy. But migrating birds can climb to 6,000m; indeed, the highest ever observed was a flock of whooper swans (*Cygnus cygnus*) at 8,800m. That's high enough to put them above low- and medium-altitude clouds, including the stratus and altostratus clouds that cover the sky on an overcast day.

Flying through a cloud is no worse than flying through the rain, though, and birds fly slowly enough that they can still turn to avoid a cliff or building that looms out of the gloom.

WHICH ANIMAL CAN PERCEIVE THE HIGHEST PITCH OF SOUND?

The greater wax moth, *Galleria mellonella*, can hear ultrasonic frequencies as high as 300kHz (humans can't hear anything above 20kHz). The moth uses this ability to listen out for the ultrasonic calls of bats. The highest frequency bat calls are only 212kHz, so the moth clearly has the edge.

HOW DO RATS SURVIVE THE TOXIC GASES IN SEWERS?

The most toxic component of sewer gas is hydrogen sulphide (H_2S), which is produced by bacteria decomposing organic matter in oxygen-starved environments. H_2S is deadly to humans at concentrations as low as 300 parts per million. The lethal concentration for rats is about 1.5 times higher, but they probably just try to avoid gas pockets. H_2S is heavier than air, so it collects in the lowest part of the sewer system. Some humans can detect its rotten egg smell at concentrations of just five parts per billion.

PHOTOS: FLPA, ISTOCK, ALAMY

IN NUMBERS

17

The number of facial expressions that have been recorded in horses by scientists at the University of Sussex.

Why don't vultures get food poisoning from eating rotten meat?

The acid in a vulture's stomach is almost 10 times as concentrated as ours. This destroys bacteria so efficiently that vulture droppings are actually more hygienic than the meat they eat! Vultures play an important role in the environment by reducing the number of contagious bacteria, such as botulism, hog cholera and anthrax. But a strong stomach isn't enough by itself, because once bacteria have multiplied in a decaying carcass, they release chemical toxins that acid can't destroy. To counter this, vultures absorb the toxins directly through the lining of their throat and then neutralise them using antibodies present in their blood.

DO BATS GET CONFUSED BY OTHER BATS' 'SONAR'?

Some bat species have a wide repertoire of available sound frequencies, so the chances of another bat happening to call on the same frequency within earshot are quite low. The Brazilian free-tailed bat (*Tadarida brasiliensis*) will, however, actively switch frequencies if another nearby bat is using a frequency within 3kHz of its own.

But research at the University of Maryland has shown that bats can actually use the echolocation calls of other bats to navigate by eavesdropping. Big brown bats will sometimes stop calling altogether if they are flying close enough to another bat, and just listen for the echo from their neighbour's calls.

PHOTOS: ISTOCK, FLPA

Why don't butterflies fly in straight lines?

Butterflies and moths use their wings for many purposes: for flight, as mobile billboards to advertise how poisonous they are, and to create camouflage patterns. So you would expect them to be less adept fliers than insects that have optimised their wing design purely for aerodynamics. But the butterfly's erratic flight is actually an evolutionary tactic that makes it harder for would-be predators to predict the insect's flightpath. The more poisonous butterflies don't need to carry out these evasive manoeuvres and so tend to fly much straighter.

Fluid dynamics simulations carried out at Kyoto University in Japan showed that butterflies achieve their trademark swoops and tumbles by generating extra turbulence with each wing beat. And high-speed photography studies from Johns Hopkins University in Baltimore reveal that they also constantly adjust their centre of gravity by shifting the position of their body and wings.

Monarch butterflies are so good at this that they can effect a 90-degree turn in less than a single body-length.

PHOTOS: FLPA

IN NUMBERS

9,000m

The height that alpine bumblebees have been shown to be able to fly at in an experiment. It means they could fly over Mount Everest, despite the thin air.

HOW MANY BIRDS MAKE UP THE BIGGEST FLOCKS?

In the UK, migratory wading birds, like knots and sanderlings, can congregate in flocks of up to 120,000 birds.

Waders are forced into huge flocks a few times a year by high seasonal tides that reduce the area of exposed mud flats for them to forage on. But there are even bigger flocks than this. The African red-billed quelea is the most numerous wild bird in the world. In good breeding years, it can form flocks of more than a million birds on the savannah. And, in 1866, a 483km (300-mile) long flock of passenger pigeons was sighted in Ontario, Canada that contained an estimated 3.5 billion birds! Incredible, considering they are now extinct.

If you fed cows strawberries, would it give their milk a strawberry flavour?

Diet definitely affects the flavour of the milk of all mammals. A 2008 study at Copenhagen University gave flavour capsules to nursing mothers and found that the taste made its way into their breastmilk within minutes. Elsewhere, dairy farmers have long known that weeds in the pasture can taint the taste of cow's milk. In fact, it's been said that French Gruyère de Comté cheese even tastes different when it is made from the milk of cows fed on mountain grass, rather than in the valley pastures.

Feeding strawberries to cows might seem extravagant, but fruit farmers often have a lot of leftover produce that isn't good enough to sell. A 2007 study looked at the practicalities of feeding leftover pears and peaches to dairy cattle, but it made no mention of any effect on the taste of the milk. This may be because fruit flavours don't hang around for long – the Copenhagen breastmilk study found that non-citrus fruit flavours only affected the milk for a few hours.

Could a dinosaur survive in today's climate conditions?

It's doubtful. Despite what *Jurassic Park* would have you believe, *Tyrannosaurus rex* and *Triceratops* lived in the Cretaceous Period. This ended 66 million years ago. The average global temperature at the time was about 4°C higher than today, with much less difference between the temperature at the Equator and the poles. The sea temperature averaged 37°C, so even tropical seas today would be too cold for marine life of the time. But land dinosaurs would be quite comfortable with the climate of tropical and semi-tropical parts of the world today. That is, until they all died of altitude sickness. Studies of air bubbles trapped in amber show that the atmosphere of the Cretaceous may have had up to 35 per cent oxygen, compared to today's 21 per cent. For *T. rex*, this would feel like being at the base camp of Everest. In such thin air, dinosaurs would be too breathless to chase hapless tourists.

PHOTOS: SOLENT NEWS, POPCORN PR, GETTY

BLUE LAGOON

The town of Useless Loop is far more productive than its name suggests. The town, nestled in Western Australia's Shark Bay, is dominated by the strikingly blue evaporative lagoons that are used to harvest vast quantities of salt.

Around 1.3 million tonnes of the stuff is produced each year by evaporating water from an operational ar.a stretching across 87km². "Shark Bay is extremely hot and dry," explains Dr John Statton of the University of Western Australia. "High evaporation rates and low rainfall make it ideal for a solar salt mine."

While the region's climate and salinity – the seawater is around 50 per cent saltier than in the open ocean – makes it easy to produce salt in huge quantities, the spotlessness of the water improves its quality. "Because the environment is so clean and near-pristine, the salt mine is able to extract very high purity salt that commands a premium price," Statton says.

The salt is used for various purposes, including food preservation and the production of caustic soda and chlorine.

PHOTO: SIMON BUTTERWORTH

TECHNOLOGY

Games consoles, cyber attacks, fitness trackers, phone hacking, super-computers, YouTube, robotic surgery, smartphone apps...

HOW PRECISE IS ROBOTIC SURGERY?

Pictured is the Da Vinci robotic surgery system. It's an arrangement of four spider-like arms operated by a surgeon at a control panel in the operating theatre just a few metres from a patient. The surgeon uses it to control, for example, the tip of a scalpel with sub-millimetre accuracy. Incisions can be smaller than in conventional surgery and there is less bleeding, reducing recovery times in prostate operations from six to two weeks.

When a surgeon moves their hand, the instrument tip only moves a fraction of that distance, allowing more precise movements – as little as 1mm for every 3mm moved by the surgeon's hand. The doctor also uses a 3D vision system, along with a camera inside the patient, so that the procedure can be viewed in minute detail.

What is the biggest object to be 3D printed?

Architects have actually 3D printed an entire room of a house. They're constructing an Amsterdam Canal House and all 13 rooms will eventually be 3D printed. The 'Kamermaker' (Dutch for 'room maker') printer is 6m tall and is a scaled-up version of the earlier Ultimaker. It will fabricate the entire house from sections up to 3m high and 2m thick. It builds the components layer by layer by squeezing melted plastic at 170°C through the print head. It's controlled by software that converts the 3D design into layers.

Also fabricating building structures on a large scale is Branch Technology, a Tennessee start-up. Their print head is attached to a 3.5m robotic arm on a 10m rail. It uses carbon fibre and plastics to produce objects up to 17m high. These can be entire external walls. The complex matrix-like geometrical forms are light and strong, and can be clad with conventional materials like concrete.

What's the highest resolution camera?

This will be a 1.8-gigapixel surveillance camera that's been built by the US military research agency DARPA. The ARGUS-IS (Autonomous Real-Time Ground Ubiquitous Surveillance Imaging System) straps together a matrix of 368 smartphone cameras into a pod flown on an unmanned aerial vehicle.

The results are truly impressive. The camera's resolution is sharp enough to show up individual people 6km (3.7 miles) below, while a single image captures an area over 7km (4.3 miles) across.

Can you get a computer virus from watching YouTube?

You should be safe just watching a video, but be wary of clicking on ads as these can turn out to be malicious. Indeed, in September 2014, scammers served up dodgy adverts on YouTube and other big sites such as Yahoo! and Amazon. The ads redirected users to a site that detected vulnerabilities in their machine's browser and in applications like Java and Flash. The website then automatically downloaded malware tailored to the computer's specific vulnerability.

PHOTOS: CAMERA PRESS, DUS ARCHITECTS, BAE SYSTEMS/DARPA

TOP TEN

SUPER-COMPUTERS

THE FASTEST MACHINES ON THE PLANET

1. Tianhe-2 (aka Milky Way 2)
National Super Computer Center, China
33.86 petaflops

2. Titan
DOE/SC/Oak Ridge Laboratory, USA
17.59 petaflops

3. Sequoia
DOE/NNSA/Lawrence Livermore National Laboratory, USA
17.17 petaflops

4. K Computer
RIKEN Advanced Institute for Computational Science, Japan
10.51 petaflops

5. Mira
DOE/SC/Argonne National Laboratory, USA
8.59 petaflops

6. Piz Daint
Swiss National Supercomputing Centre, Switzerland
6.27 petaflops

7. Shaheen II
King Abdullah University of Science and Technology, Saudi Arabia
5.54 petaflops

8. Stampede
Texas Advanced Computing Center/University of Texas, USA
5.17 petaflops

9. JUQUEEN
Forschungszentrum Juelich, Germany
5.01 petaflops

10. Vulcan
DOE/NNSA/Lawrence Livermore National Laboratory, USA
4.29 petaflops

HOW DO GOVERNMENTS PREVENT CYBER ATTACKS?

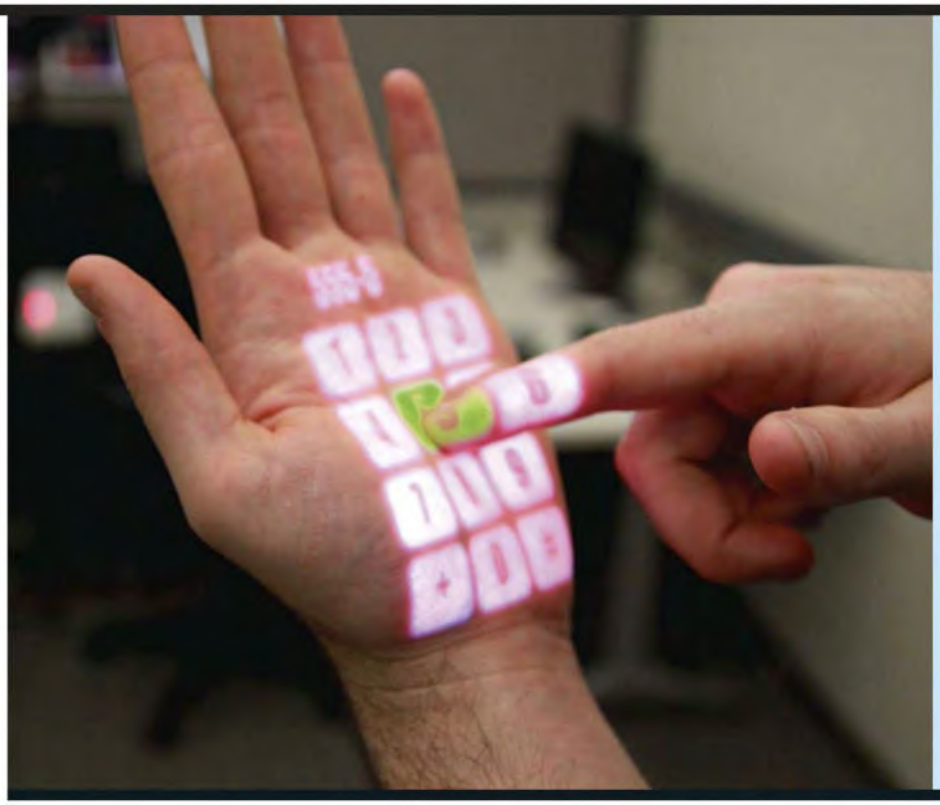
In 2007, much of Estonia was knocked offline by cyber attacks that had originated in Russia. State, business and banking websites were overwhelmed by a barrage of requests for information in so-called distributed denial of service (DDoS) attacks. A year later, a cyber defence centre was established in the country and Estonia is now a leader in national cyber security.

Most governments base their defence plans on prevention, detection and response. This is based partly on intelligence to spot threats from criminal organisations or, on occasion, even hostile governments. Somewhat controversially, this involves harvesting terabytes of data on web traffic and mobile phone communications.

Is it really possible to control a robot with your mind?

Yes it is. The US defence research agency (DARPA) has a brain-controlled prosthetic arm for upper limb amputees. As the user thinks about various movements, the arm picks up the responding brain signals that appear in the remaining nerves at the site of the amputation. With incredible dexterity, the user can remove a letter from an envelope and even move eggs from one box to another.

Away from government-funded research projects, hobbyist and engineer William 'Chip' Audette in Vermont controls a small toy robot using his brainwaves. He's using open hardware called OpenBCI where electrodes on his head pick up brainwaves. The level of control is crude, but is proof that advances in EEG technology, machine learning and robotics really are ushering in an age where we can control devices through the power of thought.



WHEN WILL WE SEE THE END OF COMPUTER KEYBOARDS?

It's impossible to say when, if ever, we're going to kill off the QWERTY keyboard. But other technologies are typing out its death warrant. Many of us are already using touch-and-swipe devices like tablets. Microsoft Research and Carnegie Mellon University are working on a system called 'OmniTouch'. It combines picoprojectors and movement-tracking software that will allow you to project virtual keypads on to any surface, even your hand.

How accurate are fitness trackers?

Fitness trackers work by using accelerometers worn on your wrist, waistband or shoe to count your strides and convert that to an approximate measure of the distance travelled and calories burned. Some also include altimeters, giving you extra credit for climbing stairs and hills. A 2014 study at Iowa State University compared them to more sophisticated laboratory equipment and found that most fitness trackers have error margins of between 10-20 per cent. Over a period of a week, that error adds up to about one day's worth of exercise.

HOW DOES LIGHT TRAVEL DOWN A FIBRE-OPTIC CABLE?

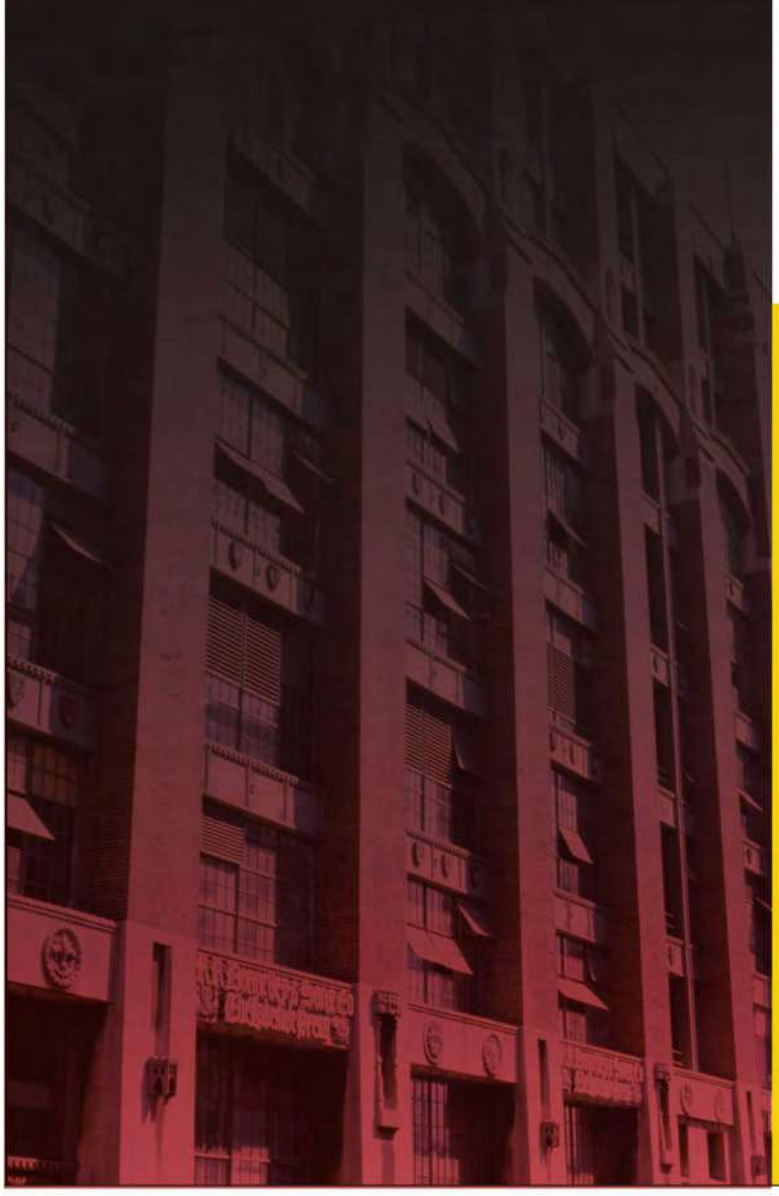
At the core of the cable is a strand of plastic or pure optical glass about 0.01mm in diameter. Surrounding it is a highly reflective cladding with a different refractive index to that of the core. The refractive indices of each material are engineered to ensure that light always reflects back off the cladding and is never absorbed by it, regardless of whether the cable is straight or bent round. It's a bit like carrying a torch through a long winding tunnel lined with perfect mirrors.

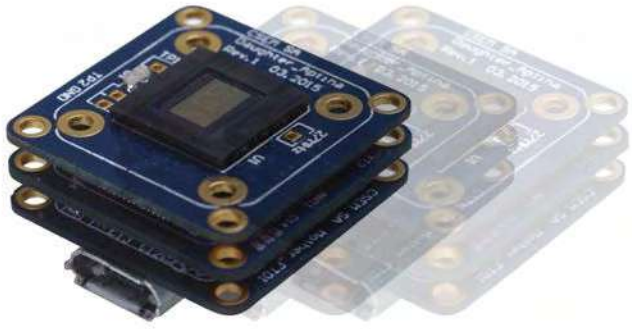
PHOTOS: CORBIS, CARNEGIE MELLON UNIVERSITY, GETTY, ISTOCK

Where is all our digital data stored?

If our data is in the cloud, the answer is that we don't know where it is – our files will be spread across data centres anywhere in the world. Because most cloud providers back up the data across multiple sites, your files may well exist simultaneously in more than one place, possibly across different countries, even continents.

Your bits and bytes might, for instance, find their way to a data centre like the massive facility at 350 East Cermak in Chicago, reputedly the biggest such storehouse in the world. It occupies a former printer's/telephone exchange, and houses storage and processing equipment over an area of 100,000m². The servers have a cumulative capacity of 3,000 years' worth of uncompressed video. But that kind of storage is energy-hungry, too. The Chicago facility consumes 100MW, the city's second-largest electricity bill after O'Hare International Airport.





WHAT IS THE WORLD'S SMALLEST CAMERA?

It's the VIP, developed by Swiss company CSEM. VIP stands for Vision-In-Package. The optical sensor chip is 0.8mm across and sits on a package containing its own processor, performing tasks such as image compression and error correction. The package is smaller than a stock cube and even has its own Bluetooth transmitter. Being self-contained and low power, it's aimed at a broad range of applications, from robotic surgery to drones.

Why does turning a device off and on often solve issues?

Many devices run some kind of computer code. The software often runs in a loop, executing commands repeatedly while the device awaits input. For instance, your screen constantly refreshes until you press a button. Sometimes, the code slips into a non-functional permanent loop that only breaks when you reset everything by switching the device off and on.

Can you prevent your phone being hacked?

You can never completely avoid your phone being hacked. You could stay off the network altogether, but that would defeat the object of having a mobile phone. Even then, you are vulnerable to any opportunist who happens to find your handset lying around.

In the tabloid newspaper phone hacks, imposters accessed victims' voicemails by guessing the appropriate PIN, so being savvy about your voicemail password. Changing it from the default is the first step in foiling the hackers. But it's not only about protecting your voicemail, as data on your phone could also be at risk. Avoid storing passwords on the device; if you absolutely have to, do so using a secure app. Another security tip is to switch off the text auto-complete function, so at least if your phone does fall into the wrong hands, it would be harder to trick the device into betraying your personal info.

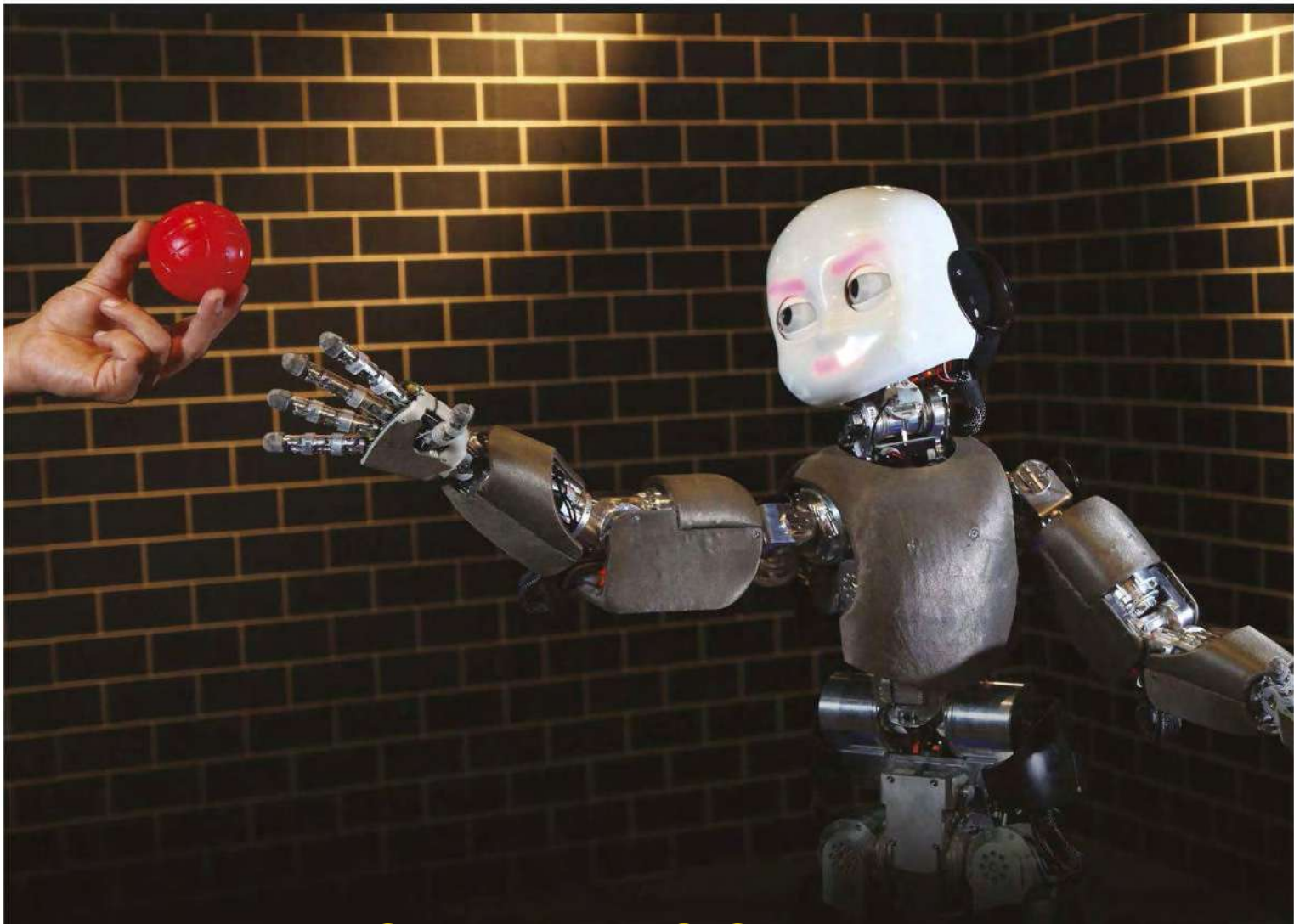
DID YOU KNOW?

Google's original name was BackRub, "a 'web-crawler' designed to traverse the web".

WILL WE EVER RIDE LANDSPEEDERS?

The landspeeders and speeder bikes in *Star Wars* work using 'repulsor fields' – a kind of antigravity. Scientists working on the ALPHA experiment at CERN have investigated whether antimatter – particles with the same mass as ordinary matter but opposite charge – might 'fall upwards', exhibiting a kind of antigravity. So far, however, there have been no conclusive results, so if you want a fast, floor-hugging chariot, your best bet is a ground effect vehicle. Looking like a cross between an aircraft and a hovercraft, these use the aerodynamic interaction between the vehicle's wings and the surface to fly just a few metres above the ground. Disclaimer: we can't guarantee that you'll look as remotely cool as you would on a landspeeder, though.

PHOTOS: ISTOCK X3, LUCASFILM LTD/IMAGE.NET



WHAT'S THE MOST HUMAN-LIKE ROBOT?

Developed by Boston Dynamics, a Massachusetts robotics firm, PETMAN is a humanoid 'bot that walks, bends and waves its arms. It has been designed to help the US military test chemical protection suits by mimicking the body movements of actual soldiers. PETMAN's gyrations are uncannily realistic, but he is not exactly interactive. He is not designed to talk or respond to users.

The iCub scores more highly in that department. Produced through a collaboration of European research institutions, the robot is about the same size as a human toddler and, unlike PETMAN, has a human-like face. While its features are quite basic, the iCub possesses eyes – indeed, some versions even have eyelids. Possibly because it is so infant-like, the iCub is one of the most convincing human mimics. Its main goal is to aid research into the cognitive development of children.

IN NUMBERS

15.72m

The length of the largest walking robot in the world. It is designed to look like a dragon and can even breathe fire!

HOW DO WIKIPEDIA ARTICLES STAY ACCURATE?

Anybody can write or edit Wikipedia articles. In August 2014, a YouGov poll concluded that Wikipedia is more trusted than the BBC. Specifically, 64 per cent said they trust Wikipedia "a great deal" or "a fair amount" (the figure for BBC News was 61 per cent, while red-top tabloid newspapers scored 13 per cent).

Wikipedia has three core policies: neutral point of view, verifiability and data coming from published and reliable sources. An article's revised section is displayed alongside the previous version so erroneous contributions are rooted out. Wikipedia's writers and editors create watch lists and are alerted if an article in which they have some expertise has been modified. Wikipedia also has a style manual to ensure control of language and layout.

DID YOU KNOW?

The first computer mouse, invented by engineer Dough Engelbart in California in 1964, was carved from wood.

Would it be possible to make a new internet?

The internet dates back to ARPANET, a computer infrastructure built in the 1960s by the US Defense Department to link research labs around the country. These days, the net is a sprawling collection of servers and computer systems around the world. For a network to be part of the internet, it must exchange information according to internationally agreed protocols. Being a network of networks, one can think of the overall internet as a mosaic of mini-internets. So private networks, or 'intranets', might qualify as a 'new' internet: they're self-contained internets based on the same protocols as the wider net. But the idea of anyone building a new global infrastructure with its own protocols seems pretty far out.

HOW LONG DOES IT TAKE A GAMES CONSOLE TO BE DEVELOPED?

Development work started on Sony's PS4 in 2008, less than two years after the much-delayed PS3 went on sale. But it wasn't until five years later, in February 2013, that the PS4 was announced. The design was unveiled that June, with the console finally being released in November in time for Christmas. Microsoft's rival Xbox One went on sale, in some territories at least, at the same time. It's unclear exactly when work on it began, but prototypes were reportedly in the hands of games developers in March 2011.

PHOTOS: PRESS ASSOCIATION, ALAMY, ISTOCK

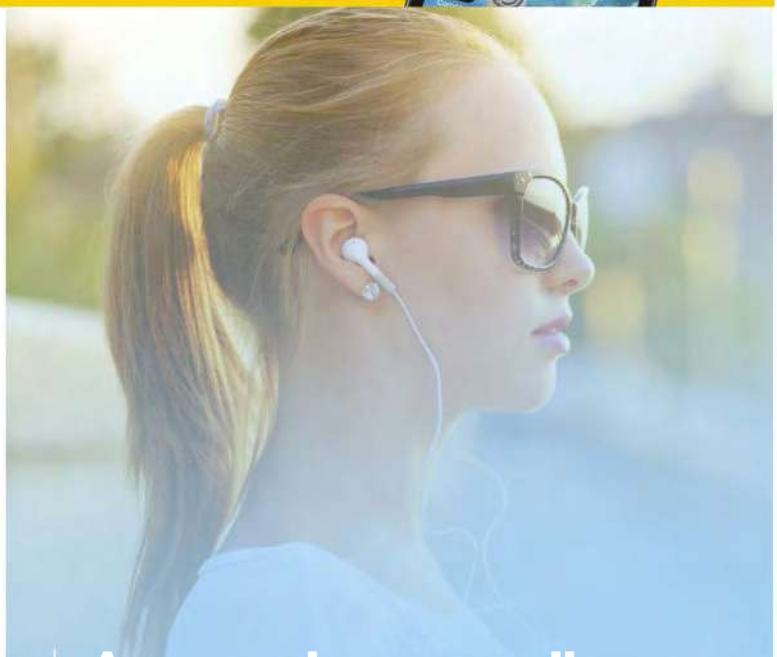
How can phones get thinner and lighter yet improve their features?

To get better features, you need greater processing power, and to get that you must squeeze more transistors into the phone's chips. A handset today crams in twice as many transistors as one from two or three years ago. It's a feat of miniaturisation where each component is smaller and lighter, allowing you to squeeze more processing out of a slice of silicon. Battery improvements are not quite as dramatic, but lithium-ion devices store ever more charge per kilogram, doubling performance since the 1990s.

What are the most popular smartphone apps in the world?

The most recently compiled worldwide figures date from 2013 and were collated by the analysts Global Web Index. At the time, there were 970 million smartphone users worldwide. Google Maps is the most popular app of all, followed by Facebook.

At number five is Wei Xin. Never heard of it? It's a free instant voice messaging app that's massive in China. Dominating in such a large smartphone market, Wei Xin is in the global top five despite only being used in China, Malaysia and Hong Kong.



Are earphones really damaging to health?

Doctors have long warned of the effects of prolonged exposure to loud music via earphones. Yet while being exposed to loud noise from, say, machinery can lead to permanent damage, evidence that music from portable devices does the same has remained elusive – until now. Studies conducted by Dr Martine Hamann and her colleagues from the University of Leicester have shown that loud noises strip nerve cells of their protective coating, stopping them reliably transmitting signals from ear to brain.

This confirms previous studies showing that even brief exposure to loud music can reduce the ear's sensitivity. But the finding also explains why evidence of permanent damage has been elusive. Dr Hamann found that nerve cells repair themselves, replacing the outer layer after a few months – if given the chance.

PHOTOS: ISTOCK X4, CORBIS

HOW DO COMPUTERISED FIREWORK DISPLAYS WORK?

In a computerised firework display, the pyrotechnics are detonated by electric matches – or e-matches. The e-match head contains a zirconium compound that ignites readily when heated, the heat coming from a coil of wire encasing the head. The e-matches are triggered remotely from controllers called electronic firing panels, which have banks of switches assigned either to individual pyrotechnics or batches to be fired simultaneously. The more advanced panels run automatically from computer code, which is often programmed using specialist pyrotechnic software and then downloaded to the panel before the display. Using software to launch a display is open to error, however, as seen at the San Diego 2012 Fourth of July celebrations when a glitch triggered all the fireworks at once. Now that is one big bang.

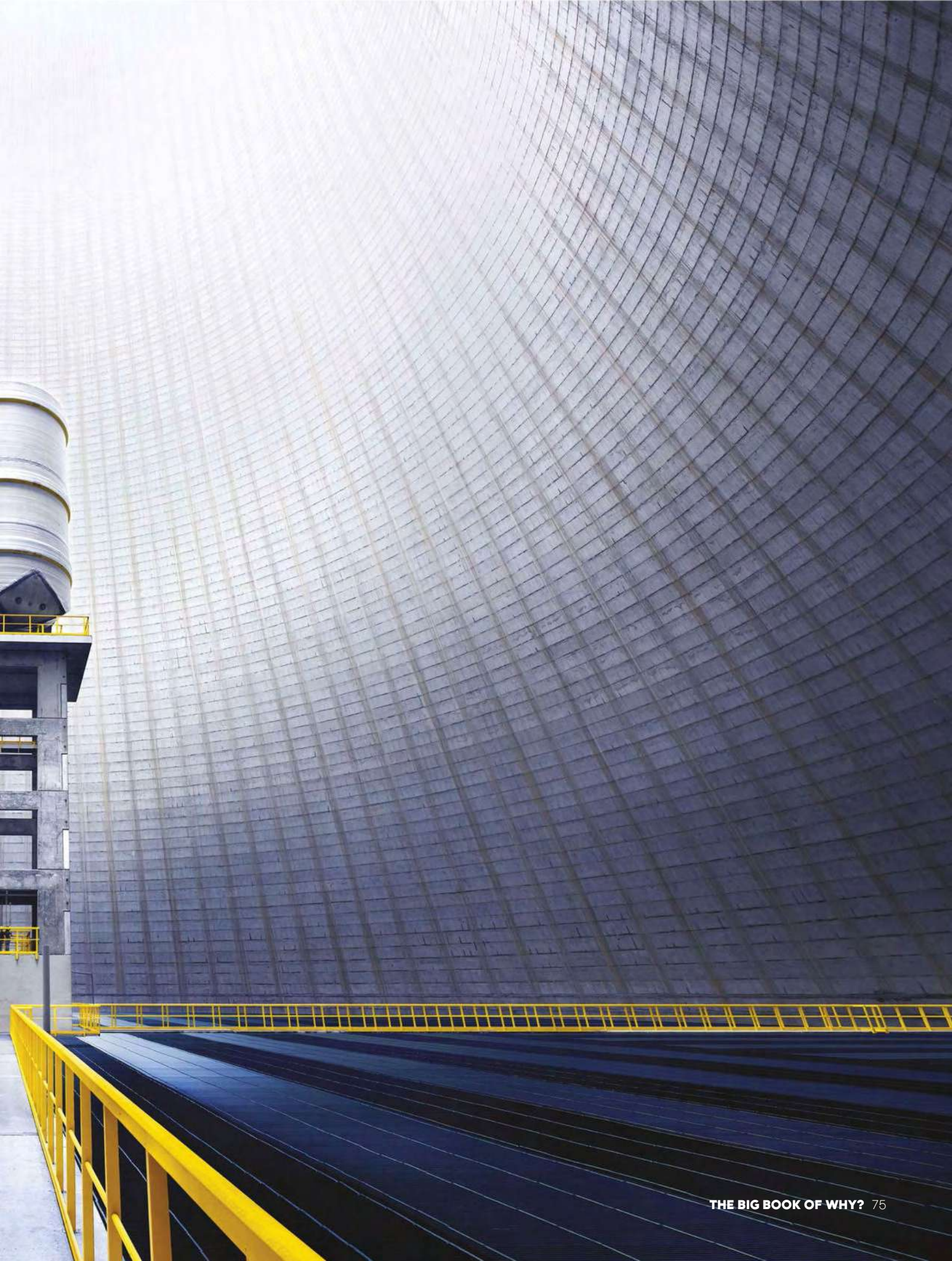
GREEN STEAM

Welcome to the cavernous innards of the Lünen coal-fired power plant's cooling tower. Situated near Dortmund, Germany, the tower stands 160m tall and 108m wide: it would take more than 48 million party balloons to fill it. It can burn 240 tonnes of coal per hour and generates 750 megawatts of power. The coal is burned in fresh air at 1,300°C, producing 2,000 tonnes of steam to drive the turbines. The tower is then used to help condense the steam back down to water.

"Around 60,000m³ of cooling water per hour is forced into the tower by two huge pumps," says Stefan Paul, MD of Trianel, the energy company that operates the station. "Most of it drips down and is pumped back to the machine room. The remaining portion leaves the tower in the form of water vapour clouds."

The tower mixes and disperses cleaned flue gas from the plant, helping to improve efficiency. The plant is around 46 per cent efficient, making it one of the best performing of its type in Europe. Adding to its green credentials, an area of land has been set aside for the future addition of a carbon capture and storage plant.

PHOTO: CAMERA PRESS



GENETICS AND EVOLUTION

Learning languages, deadliest viruses, Darwinism, eye defects, gender determination, inherited talent, hairy primates...

IS THE RATE OF HUMAN EVOLUTION INCREASING WITH POPULATION GROWTH?

Larger populations create more chances for genetic mutations to occur, meaning more variations for natural selection to either favour or weed out. But in big populations, it takes longer for changes to spread. The fastest rate of evolution occurs when a population is split into isolated subgroups that can't interbreed due to geographic or cultural barriers. Travel has broken down many barriers, so our genes get blended together instead of splitting into subspecies. We are actually evolving around 100 times faster than at any other period in our history, but 'modern' for an evolutionary biologist means the last 5,000 years. It's too soon to tell how our evolution has been affected by the population explosion of the last few centuries.

WHY HASN'T EVOLUTION SORTED OUT EYE DEFECTS?

Vision defects like short-sightedness aren't caused by just one single gene. There's some evidence that short-sighted people have a higher than average IQ, which may be because the same genes affect the eyes and brain.

Vision defects also often have environmental causes. Short-sightedness is more common in people who do a lot of close-up work, have saturated fat in their diet and sleep with a light on. These are all relatively new in the history of human evolution.

IN NUMBERS

206

The number of bones in an adult human's body. At birth, humans have between 300-350 bones, but many of these fuse during development.

Why do men grow beards but not women?

Men grow beards because the hair follicles on their jaw are stimulated by the hormone dihydrotestosterone, which is produced from testosterone. Women have the same number of follicle cells on their faces as men, but these are less sensitive to dihydrotestosterone, and females also have lower testosterone levels to begin with. Beards may have evolved as a signal of the testosterone levels of a man, and women came to find thicker beards attractive because it implied that their owner would be stronger or more dominant.

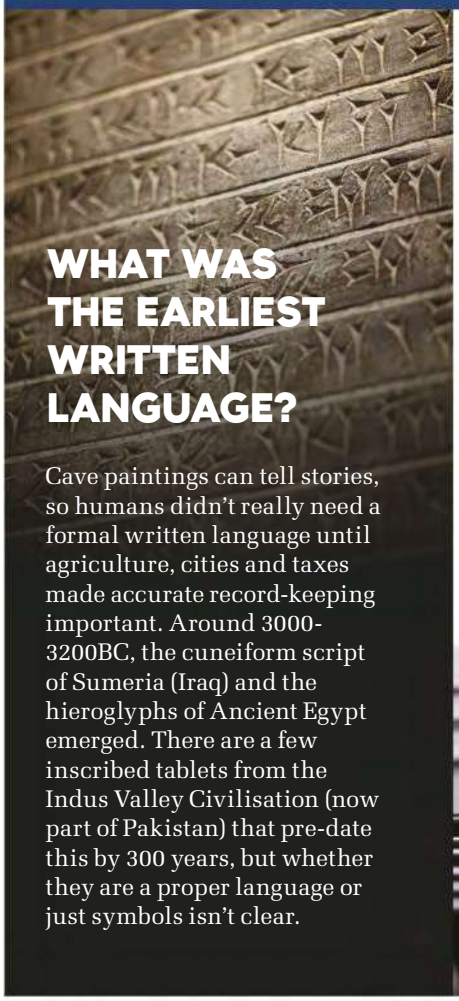
PHOTOS: ISTOCKX3

HOW IS THE SEX OF SOME SPECIES DETERMINED BY TEMPERATURE?

Temperature-dependent sex determination is seen all crocodiles and alligators, and in most turtles. The mechanism isn't well understood, but one piece of the puzzle is the enzyme aromatase, which converts the male hormone testosterone into the female hormone oestrogen. This enzyme reacts very slowly at 25°C but much more quickly at 30°C, so females hatch out of eggs that are incubated at warmer temperatures. This seems simple, except that in some species the females hatch out of the cooler eggs, and in others, males only hatch from eggs in a middle range of temperatures.

DID YOU KNOW?

The heaviest man ever was Jon Brower Minnoch who, in 1978, was estimated to weigh more than 635kg.



WHAT WAS THE EARLIEST WRITTEN LANGUAGE?

Cave paintings can tell stories, so humans didn't really need a formal written language until agriculture, cities and taxes made accurate record-keeping important. Around 3000-3200BC, the cuneiform script of Sumeria (Iraq) and the hieroglyphs of Ancient Egypt emerged. There are a few inscribed tablets from the Indus Valley Civilisation (now part of Pakistan) that pre-date this by 300 years, but whether they are a proper language or just symbols isn't clear.

Is talent genetic or learned?

Both. Some people are born with greater potential but, without hard work and practice, their talent will come to nothing. Music is a good example, with some evidence of genetic differences. For example, a study of 500 twins found that 80 per cent of tone deafness is inherited. Another found genes associated with serotonin release, which were related to musical creativity.

Chess is another good example: an analysis of 14 studies of top chess players and musicians concluded that only about 30 per cent of the variation between performers could be accounted for by their hours of practice. In contrast, a study of British musicians found that top performers had practised a lot more – but learned no faster – than less skilled players.

A popular theory is that it takes 10,000 hours of practice to become an expert at something – and there is probably a degree of truth in this. But if your genes give you an aptitude for and enjoyment of chess, maths, music or football, you are surely more likely to put in those long hours.

PHOTOS: FLPA, ISTOCKX3, ALAMY

DID YOU KNOW?

The most-spoken language is Mandarin Chinese. More than 848 million people speak it.

Do we utilise all of our genes in our lifetime?

Some genes are permanently switched off. For example, males all have an X chromosome and yet the genes on this chromosome that code for female reproductive organs are inhibited early in foetal development. Females have two X chromosomes, but only one is active in any given cell. We have some genes that don't get used because mutations have rendered them faulty. A 2012 study at the Wellcome Trust Sanger Institute found that we have an average of 100 broken genes each.

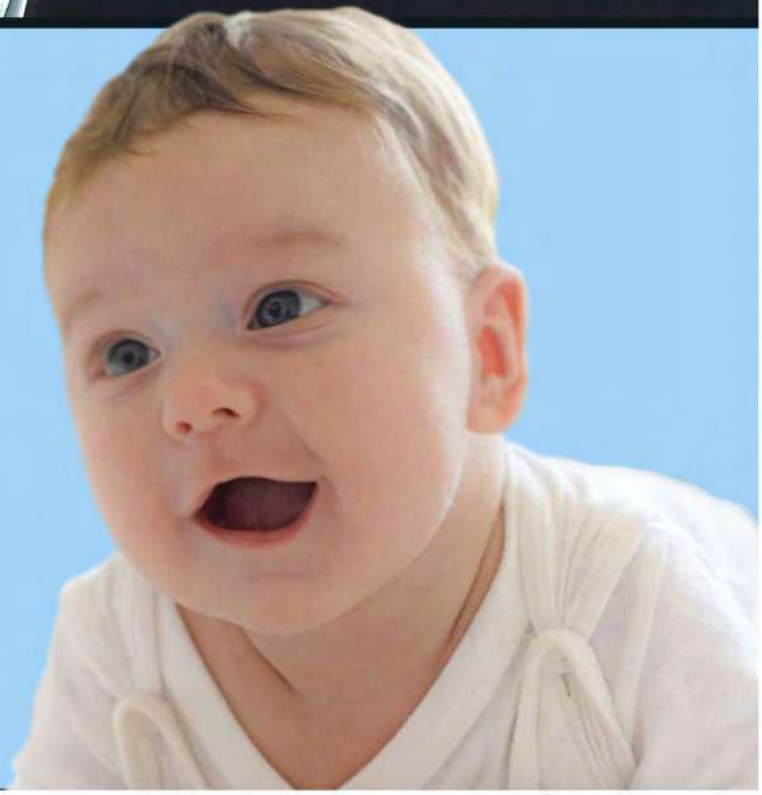
What's the oldest human DNA that's been discovered?

It's about 400,000 years old. This was DNA from a thigh-bone found in the 'Pit Of Bones' cave in the Atapuerca mountains of northern Spain. The leg bone belonged to either an early Neanderthal or a member of the human species *Homo heidelbergensis*. These are both sister species to our own *Homo sapiens*, but *H. heidelbergensis* is the older species and is thought to be the direct ancestor both of the Neanderthals and of ourselves.

These other species of the genus Homo aren't the same as a modern human though. *Homo sapiens* didn't appear for another 200,000 years and didn't migrate from Africa to Europe until at least 75,000 years later.

WHY DO BABIES LEARN LANGUAGE SO EASILY?

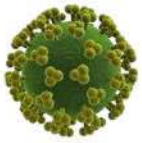
Recent research on babies' hearing may throw light on an old controversy – are our brains like blank slates, able to use any sounds equally easily and develop almost any kind of language? Or do we have a 'language instinct', with brains that have an innate capacity to learn language? Newborn Italian babies were played different sounds, some of which, like 'bl' are common in many languages, while others, like 'lb', are very rare. Using near-infrared spectroscopy, which can detect brain function without needing a scanner, they found that the babies' brains reacted far more strongly to sounds such as 'blif' than to 'lbif'. The babies were too young to have learned any words yet or even to begin babbling. So it seems as if their brains were ready prepared for the sounds of language.



TOP TEN

DEADLIEST VIRUSES

BY HUMAN FATALITIES BY YEAR



1. HIV – human
Deaths per year: 1.6 million
Spreads: via infected bodily fluids
Symptoms: weight loss, respiratory infections, rashes

2. Hepatitis B
Deaths per year: 600,000
Spreads: via infected blood
Symptoms: yellow eyes, dark urine, vomiting, abdominal pain

=3. Influenza
Deaths per year: 500,000
Spreads: via coughs and sneezes; also via bird droppings, blood and saliva
Symptoms: fever, aches, fatigue

=3. Hepatitis C
Deaths per year: 500,000
Spreads: through blood contact with an infected person
Symptoms: fever, stomach pain, itchy skin, liver disease

5. Rotavirus
Deaths per year: 450,000
Spreads: through ingestion of contaminated stool
Symptoms: vomiting, diarrhoea, dehydration, fever

6. Measles
Deaths per year: 122,000
Spreads: through direct contact with an infected person
Symptoms: fever, white spots/red blotches, vomiting, diarrhoea

7. Hantavirus
Deaths per year: 70,000
Spreads: via rodent droppings
Symptoms: facial flushing, hypotension, respiratory and renal problems

8. Rabies
Deaths per year: 55,000
Spreads: via animal bites
Symptoms: acute pain, violent movements, depression, mania, inability to swallow water, coma

9. Yellow fever
Deaths per year: 30,000
Spreads: via mosquito bites
Symptoms: fever, bleeding into skin, slow heart, jaundice, coma

10. Dengue
Global deaths per year: 25,000
Spreads: via mosquito bites
Symptoms: fever, muscle pain, rash, circulatory failure, shock

Why are humans the only primates whose head hair keeps growing?

Other primates have long head hair, too – lion tamarins, for example. It's just that the contrast is just more striking against our relatively hairless bodies. Long hair isn't a universal trait either. The races that never left Africa have shorter, curlier hair. Exactly why the humans who migrated to colder climates evolved long hair is still debated. The male preference for women with long hair is perhaps because men lose theirs as they get older, thus associating lengthy locks with femininity and youth. One possibility is that, in hot climates, the disadvantage of lots of head hair outweighed its sexual desirability, but as soon as our ancestors moved north, they were free to choose mates based on the appearance of their hair. It could also be that once we started wearing clothes, the head was the only thing that needed long hair to keep it warm.

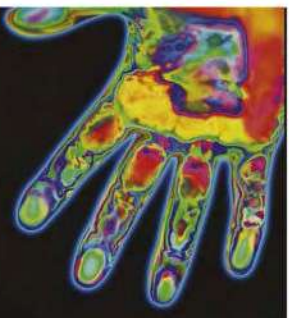
IN NUMBERS

316,600

The number of people across the world aged over 100. Estimates suggest that, by 2050, this figure could increase to more than three million.

PHOTOS: ISTOCK X8, ALAMY X3

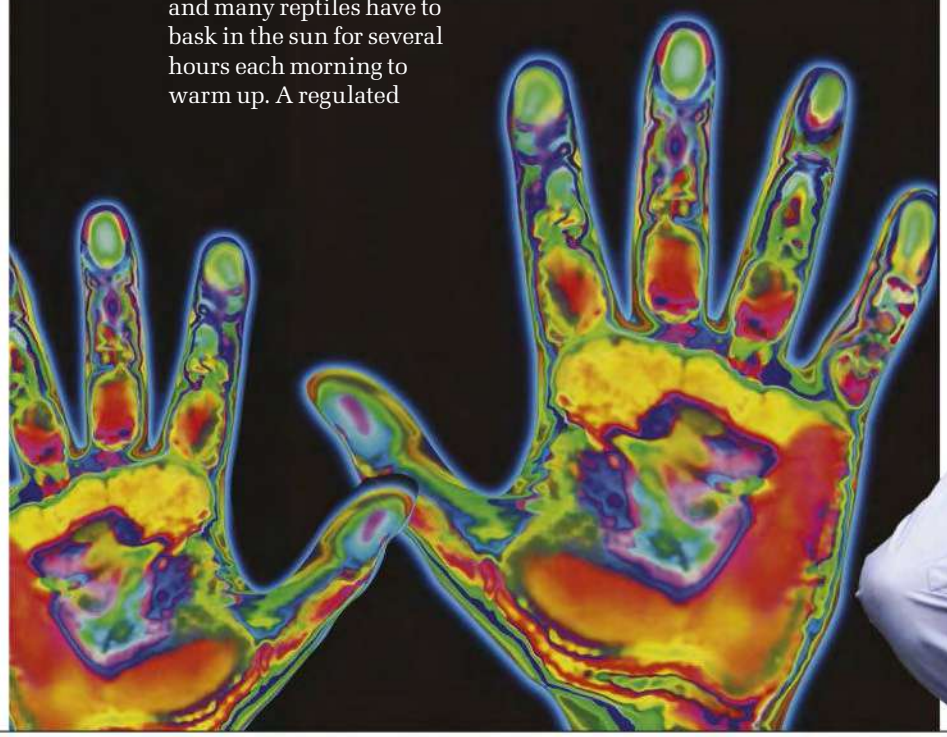
Why did we evolve warm blood?



Being warm blooded means that your body is maintained at a fixed temperature, regardless of how cold your surroundings are. The term for this is homeothermy. Less than one per cent of animals are homeothermic – it's basically confined to mammals and birds.

Homeothermic animals burn more fuel and need about 10 times as much food. However, chemical reactions generally happen faster at warmer temperatures and a warm body can work at the same activity level even in cold environments, such as at night, underground or in winter. Insects often can't fly when it is too cold because their flight muscles can't contract fast enough and many reptiles have to bask in the sun for several hours each morning to warm up. A regulated body temperature also allows you to evolve enzymes that are tuned to work efficiently within a precise temperature range. The downside of this is that hypothermia or heatstroke are enough to render our enzymes inactive and kill us.

Another possibility is that homeothermy may have evolved as a strategy for fighting infection. A 2010 study at the Albert Einstein College of Medicine in New York found that a body temperature of 36.7°C was enough to protect against most fungal infections. Mammals and birds rarely get fungal diseases, but they are a problem for fish, as anyone who has kept goldfish will know.



IN NUMBERS

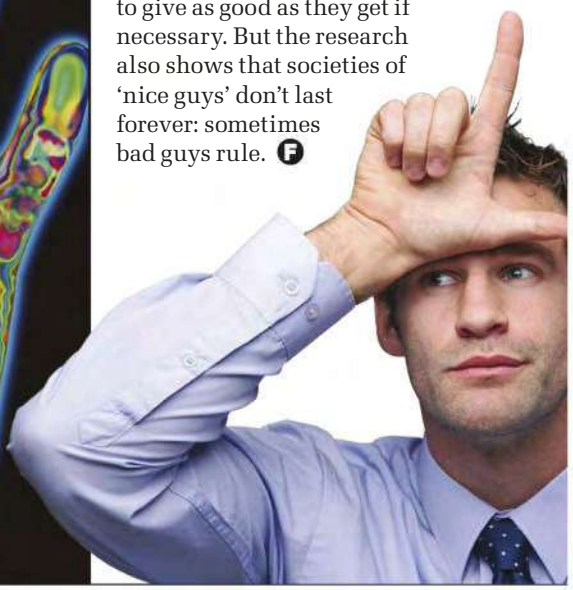
£400,000

The price that one of the world's six relatively complete *Diplodocus* skeletons was sold for at auction in 2013. It had been discovered in a quarry in Wyoming.

Doesn't Darwinism mean nice people are losers?

Darwin's theory of evolution is often summed up by the phrase 'survival of the fittest', in which 'selfish' genes favour nasty creatures over nice ones. Yet the reality is that many organisms, including humans, do better by adopting traits like co-operation and altruism.

Theoretical biologists have investigated this counterintuitive fact using computer simulations. These create virtual collections of organisms able to use various different co-operation strategies and then monitor the degree to which they thrive in the 'Darwinian struggle' over thousands of generations. The results confirm that co-operating organisms are fitter than nasty ones, but only if they also adopt certain other traits. For example, they must be willing to start out thinking the best of other organisms, and to forgive occasional transgressions – while being prepared to give as good as they get if necessary. But the research also shows that societies of 'nice guys' don't last forever: sometimes bad guys rule.



PHOTOS: GETTY, ALAMY

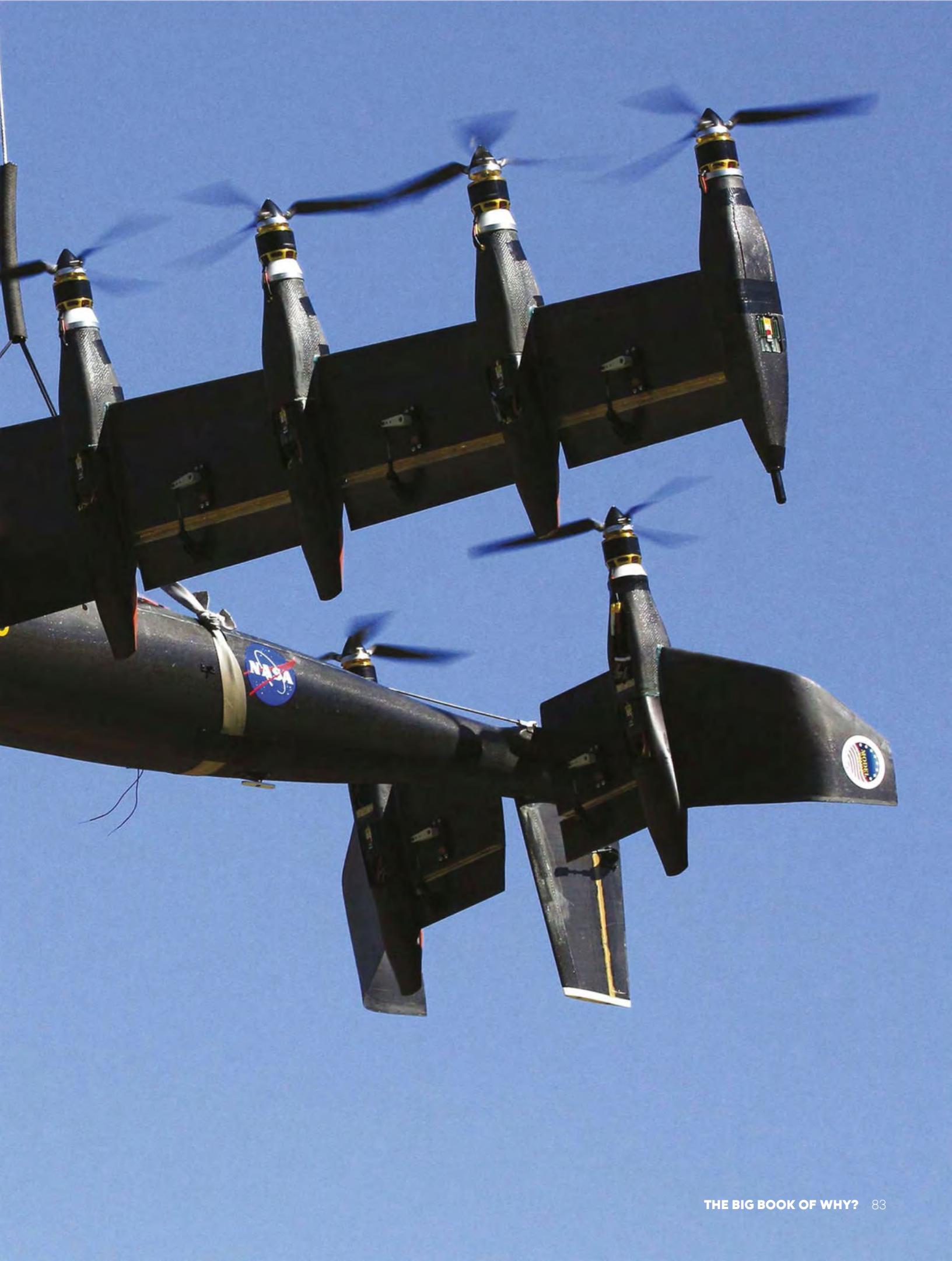
GAME OF DRONES

The tether attached to this NASA-developed GL-10 unmanned drone gives it away as a prototype. Nicknamed 'Greased Lightning', the plane has a wingspan of six metres (20 feet), can fly at speeds of up to 48km/h (30mph) and is so energy-efficient that it can remain airborne for up to 24 hours.

As shown here, the craft's wings tilt vertically upwards like a helicopter during take off and landing. Once in the air, the wings swivel forward and it flies like a conventional plane. The GL-10 uses only a quarter of the energy of a helicopter and is four times more aerodynamically efficient. Each of the 10 propellers is driven by its own electric motor, while two diesel engines charge their batteries.

"Greased Lightning is intended for civilian applications," explains NASA's William J Fredericks. "But an aircraft that can take off and land vertically, and fly efficiently, has many military and intelligence applications as well. Uses for this design range from the efficient delivery of small packages up to a personal air vehicle big enough to carry two people."

PHOTO: NASA


NASA

PLANET EARTH

Longest rivers, largest building, thunderstorms, supervolcanoes, human population, snowflakes, the origin of life, gold reserves...

HAS EARTH EVER HAD MORE THAN ONE MOON?

No observations or claims for additional moons of Earth have ever been proved. However, some astronomers have speculated that there may have been a companion moon very early in Earth's history. An impact with this 'other' moon may help explain why the Moon's nearside is low, flat and dominated by volcanic maria (or 'seas'), while the far side is mountainous and contains many craters. This possible impact can also explain the how certain chemical elements are distributed on the Moon. However, other processes can also account for these observations, so the 'other moon' idea is still a hypothetical one.

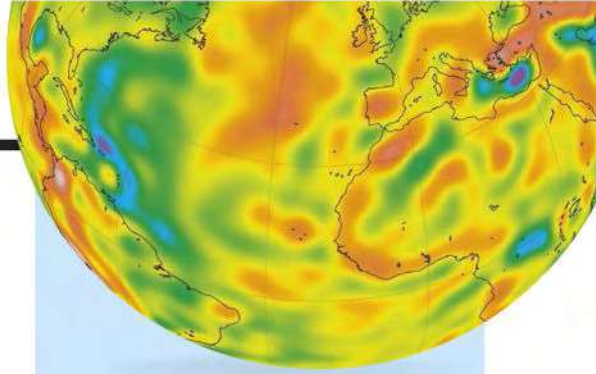
Earth does, however, have some very small satellites that could be classed as moons. In 2006, a tiny asteroid, 2006 RH120, was discovered in Earth's orbit. This 'captured' object remained in Earth orbit for 13 months before returning to a solar orbit. These 'temporary' moons are thought to be quite common.

Why are autumn leaves blown into mini tornadoes on the street?

Buildings shield us from the surprisingly strong airflows that sweep over the land at this time of the year. If these airflows strike buildings, they produce eddies and swirls just like those around a brick stuck in a stream. The resulting vortices can tip over to produce tornado-like swirls, especially around tall buildings in built-up areas.

DID YOU KNOW?

Ninety per cent of Londoners live within 400 yards of at least one of the capital's 19,500 bus stops.



DOES GRAVITY VARY ACROSS THE SURFACE OF THE EARTH?

As a rule of thumb, places near Earth's equator experience lower gravity than those near the poles, through the joint effect of the Earth's spin and equatorial bulge.

Observations by satellites show that gravity is weakest in the Peruvian mountains. But, at less than 1 per cent below the global average, you'd never be able to tell.

WHY ARE THUNDERSTORMS MORE COMMON IN THE SUMMER?

The science of how thunderstorms are triggered is still somewhat mysterious. Thunderstorms require the formation of clouds, inside which regions of positive and negative electric charges can accumulate. These lead to voltage differences so big – around 400,000V per metre – that electrons are stripped off the molecules within the cloud, forming violent electric flows that we see as lightning.

Thunderstorms are more common during summer because the necessary conditions occur most readily when there's plenty of heat. Heat triggers convection, in which air becomes hotter, less dense and rises up from the surface. Plus, air holds most moisture when it's warm. While the processes that form the electric charges are not fully understood, it's believed to involve the interaction of violently rising moist air and ice crystals at high altitude.

In the UK, suitable conditions occur on only around half a dozen days during the summer.

PHOTOS: ISTOCK X2, GETTY, SCIENCE PHOTO LIBRARY

TOP TEN

WORLD'S LONGEST RIVERS

FROM SOURCE TO MOUTH

1. Nile
6,695km
East and North Africa

2. Amazon
6,516km
South America

3. Yangtze
6,380km
China

4. Mississippi-Missouri
5,969km
USA

5. Yenisei
5,539km
Siberia

6. Yellow River
5,464km
China

7. Ob-Irtysh
5,410km
Siberia

8. Paraná-Rio de la Plata
4,880km
South America

9. Congo
4,700km
Central Africa

10. Amur-Argun
4,440km
North Asia

Why is most of the world's landmass in the northern hemisphere?

The Greek philosopher Aristotle argued that there simply had to be a huge landmass south of the Equator in order to balance out the vast amount to the north of the planet. The idea of 'Terra Australis' persisted for over 2,000 years and even appeared on maps between the 15th and 18th Centuries. It was finally debunked by Captain James Cook's expedition to find it in the 1770s.

It's now recognised that, despite appearances, the continents aren't that important, being merely slightly thicker parts of the upper crust, which itself represents barely 1 per cent of the volume of the Earth. Satellite studies of the distribution of gravity across the entire planet reveal little difference between the amount of mass in the northern and southern hemispheres. As such, the arrangement of the world's continents has little significance – and, in any case, has changed over time. Around 200 million years ago, Earth's surface was dominated by the so-called Pangaea supercontinent, much of which was actually south of the Equator. Pangaea broke up over time to form the modern continents that we're familiar with today.

Pangaea, 200-300 million years ago

Continents 135 million years ago

Continents 35 million years ago

PHOTOS: ISTOCK X5, GETTY X2, ALAMY, SCIENCE PHOTO LIBRARY X3, PETER MILOSEVIC/WIKI, NASA/JSC

IS THERE A LIMIT TO THE HUMAN POPULATION ON EARTH?

In 2002, Harvard University sociobiologist Edward Wilson estimated that the amount of available arable land in the world would be enough to feed a maximum of 10 billion people. This assumed that they were all vegetarians. However, if everyone on the planet had the same eating habits as the average American, then there would need to be four Earths to support them. Drinking water may be more of a constraint since only 3 per cent of the Earth's water is freshwater and most of that is locked in ice caps or other inaccessible places.

In principle, these problems could be overcome. Earth receives more energy from the Sun in an hour than humanity uses in a year. If we harnessed more of this energy, we could produce drinkable water from the sea and create food from bacteria or algae.

But this assumes that our species will multiply indefinitely – and that isn't borne out by current trends. According to the United Nations Population Division, the rate of growth of the human population has been falling since 1963. As countries become more industrialised and infant mortality rates fall, the birth rates seem to drop as well. By 2050, global population is predicted to stabilise at between 8 and 10.5 billion and it may even decline after that. The limit to human population may be our own desire to reproduce, rather than Earth's capacity to support us.

IN NUMBERS

3.04 trillion

The number of trees on the planet. However, that number is rapidly diminishing, with humans responsible for cutting down around 15.3 billion trees every year.

WHY DOES WIND BLOW IN GUSTS AND NOT AT A STEADY RATE?

Wind is simply the flow of air from areas of high pressure to those of lower pressure, and obeys the same laws of physics as fluids. Wind is no more likely to flow steadily and smoothly over the Earth than water, and we experience the resulting changes in flow as gusts.

Why don't we get big earthquakes in the UK?

Big earthquakes are caused by tectonic plates sliding past each other in a juddering motion. This builds a massive amount of pressure before it's released suddenly and unpredictably. The UK is on the Eurasian plate, about 1,600km (1,000 miles) from the nearest boundary to the west. And it's moving away from the neighbouring plate, so there's no energy build-up.

DID YOU KNOW?

The deadliest volcanic eruption ever recorded was in 1815 when the Indonesian volcano Tambora claimed 71,000 lives.

How many elements make up our planet?

There are 118 elements in the periodic table, 98 of which occur naturally on Earth. But just eight (iron, oxygen, silicon, magnesium, sulphur, nickel, calcium and aluminium) make up almost 99 per cent of Earth's mass. Carbon, present in every living thing, accounts for just 0.07 per cent of Earth's mass. When the planet formed, denser elements sank to the core.

The crust has a higher percentage of lighter elements, like oxygen and aluminium, and much less iron than the planet as a whole. Elements 83 and above are radioactive and are gradually disappearing due to radioactive decay; above number 98, this decay is so fast that the elements are only found in the laboratory. The last element, ununoctium, is so unstable that only three or four atoms have ever been detected.

Could life have originated deep inside Earth?

The idea that life could thrive deep below Earth's surface was once regarded as heretical. Lacking any obvious source of energy, such as sunlight, and subjected to intense heat and pressure, subterranean organisms would seem to have little chance of survival. Yet since the 1980s, bacteria, fungi and worm-like creatures have been found lurking kilometres down in mine boreholes and deep sea sediments. These organisms have extraordinary sources of energy. For example, some bacteria rely on the reactions between water and rocks to receive their energy.

Dating techniques suggest bacteria have existed at depths of several kilometres for at least 30 million years. What isn't clear is where they fit in to the history of life on Earth: were they washed down or are they progenitors of life on the surface? Either way, their existence has boosted hopes for life on Mars. While none has been found on the surface, NASA's Curiosity rover has detected methane coming from within the planet – and this may be the result of subterranean organisms.

HOW DID EARTH GET ITS NAME?

Each language has its own name for our planet, but all have one thing in common. Each is derived from a word meaning 'ground' or 'soil' (or sometimes 'universe' or 'creation').

For example, the modern English word 'Earth' derives from the Germanic 'erde', meaning 'ground'. The roots of such words all date from a time when humankind was unaware that Earth is actually a planet. They merely signified the ground beneath our feet, and were adopted for the planet later on.

PHOTOS: ISTOCK X3, ALAMY, GETTY, SCIENCE PHOTO LIBRARY

HOW MUCH SALT IS IN THE DEAD SEA?

The Dead Sea has a salinity of 33.7 per cent, almost 10 times saltier than ordinary seawater. If you evaporated a litre of Dead Sea water, you'd be left with around 250g of salt; in the whole of the Dead Sea, there are about 37 billion tonnes of the stuff. Ordinary sea salt is 97 per cent sodium chloride, whereas Dead Sea salt is a mixture of different chloride and bromide salts. Ordinary sodium chloride only makes up about 30 per cent, which would still enough to supply the entire population of the UK with cooking salt for 70,000 years!

IN NUMBERS

122.5

The extraordinary number of carats (one carat = 200mg) of a rare blue diamond found in 2014 in South Africa's Cullinan mine. It was sold for almost $28m.

What's the world's largest building?

As measured by total floor area, the largest freestanding building is the New Century Global Centre, a shopping mall in Chengdu, China. It's big enough to hold 16 Wembley Stadiums or 20 Sydney Opera Houses. At 1.7 million square metres, the floor area is almost four times the size of Vatican City.

PHOTOS: ISTOCKX2

AT WHAT ALTITUDE CAN YOU SEE THE CURVATURE OF EARTH?

From Felix Baumgartner's world record skydive to teddy bears carried aloft in balloons, we're all familiar with photos taken from 'the edge of space', with the curvature of the Earth in clear view. It's all a bit of an exaggeration, though: even Baumgartner's 39km (24-mile) high jump was well below the 100km (62-mile) height usually taken to be where space begins.

Passengers on Concorde were able to see the curvature of Earth, implying that an altitude of 18.3km (60,000ft) is more than enough. Pilots and cabin staff flying considerably lower have sometimes claimed to have seen the curvature too, but there's long been a suspicion that they were being fooled by optical distortion by windows. To get to the bottom of the mystery, Dr David Lynch, of California-based optics consultancy Thule Scientific, carried out a detailed analysis, published in the journal *Applied Optics* in 2008. He concluded that it's just possible to see the curve of the Earth at around 10.7km (35,000ft) – given perfect conditions. This suggests that the curvature of Earth can be seen from heights barely 10 per cent of the height of the threshold of space.

PHOTOS: PRESS ASSOCIATION

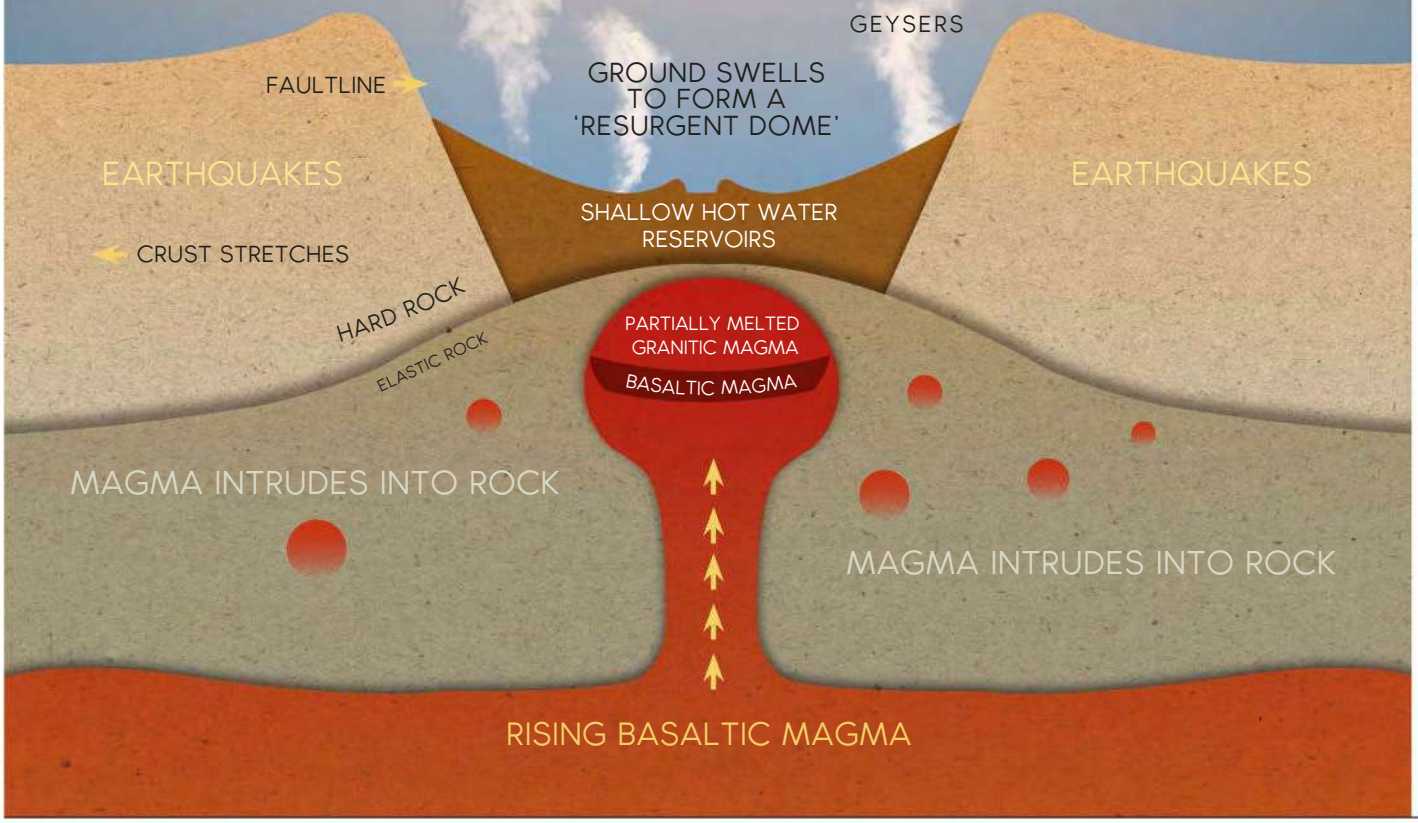
Can lightning strike upwards?

Yes – and scientists at ZT Research in South Dakota have caught the phenomenon on camera. The footage revealed that a conventional lightning bolt can trigger a change in the electric field in the atmosphere. Any tall building in the area is then liable to act like a lightning conductor in reverse, sending a bolt back into the clouds.

What are 'supervolcanoes'? And how many are there?

They're not volcanoes in the traditional sense, but vast subterranean magma chambers whose past explosions have released at least 300 cubic kilometres of debris – over 100 times that produced by normal eruptions.

Around 20 have been identified so far – including under Yellowstone Park, Wyoming – and the last one erupted 27,000 years ago in New Zealand. The eruption of one of these could have a global impact on the environment.



PHOTOS: WALT LYONS/WEATHERVIDEOHD.TV

WHERE DID EARTH'S WATER COME FROM?

It's a bit of a mystery. Explanations divide into two camps: endogenous, meaning the water came from Earth itself, and exogenous, meaning it was dumped here from elsewhere. For example, one endogenous possibility is that water molecules were formed from hydrogen and oxygen molecules combining inside the early Earth, and emerging as steam in volcanic eruptions. Alternatively, ready-made water molecules may have been delivered here by comets. Until recently, astronomers were sceptical of the comet theory, as it could not explain the fact that around 0.3 per cent of oceanic water contains an unusual form of hydrogen called deuterium. However, in 2011, astronomers found deuterium-based water on comet Hartley 2. While not proof that we've all been drinking comet debris, it keeps this intriguing possibility alive.

HOW MUCH GOLD IS THERE IN THE WORLD?

For millennia, gold has been coveted for its beauty – and its rarity. According to the World Gold Council, there are currently around 184,000 tonnes sitting in bank vaults, government reserves and personal collections. That sounds a lot, but just one cubic metre of the stuff weighs more than 19 tonnes. Thus, all the world's known gold reserves could be laid out on a football pitch in a layer only a metre or so high.

But this is only the gold that has been mined and documented. Estimating how much actually exists on the planet is much trickier. Chemical analysis of rock samples suggests gold makes up, on average, a few parts per billion of the total mass of the Earth's crust. That means the top kilometre or so has around a million tonnes of the stuff still to be dug up. It probably never will be, though, because most will be hopelessly uneconomic to extract. This was learned by the German chemist Fritz Haber who, in the 1920s, hoped to pay his country's war reparations by chemically precipitating the gold dissolved in the world's oceans. But the concentrations were simply too low; each litre of seawater contains just 13 billionths of a gram of gold.

Is every snowflake really unique in shape?

There's very little chance of any two of the classic six-sided, spiky snowflakes exactly matching each other in every detail. But that's not the only type of snowflake: some are far less complex – and two looking remarkably similar were found by American scientists on a collection plate aboard an aircraft in November 1986. F

PHOTOS: SCIENCE PHOTO LIBRARY, GETTY

THRILLED TO BITS

Resembling the world's most advanced model kit, the 3,500 components that make up the Bloodhound SSC supersonic car are laid out in the team's headquarters. Perched in the driving seat is Wing Commander Andy Green, the man who'll be behind the wheel when the vehicle attempts to break the land speed record in the Kalahari Desert later this year.

Ultimately, the team aims to reach a top speed of 1,600km/h (1,000mph), almost 400km/h per hour faster than the current land speed record set by Green in ThrustSSC in 1997. Before then, however, it has to be put back together.

"The thousands of components all fit together like a 3D jigsaw," explains Bloodhound's Jules Tipler. "After being manufactured, the components are trial-assembled and, where appropriate, bonded and riveted together, which is what's happening here. Eight aerospace and motorsport technicians, supported by four technicians from the Royal Electrical and Mechanical Engineers, will take six weeks to do the final assembly."

PHOTO: BLOODHOUND PROJECT


Warning
FORK LIFT THIS END
FORK LIFT THIS END

MATHS AND PHYSICS

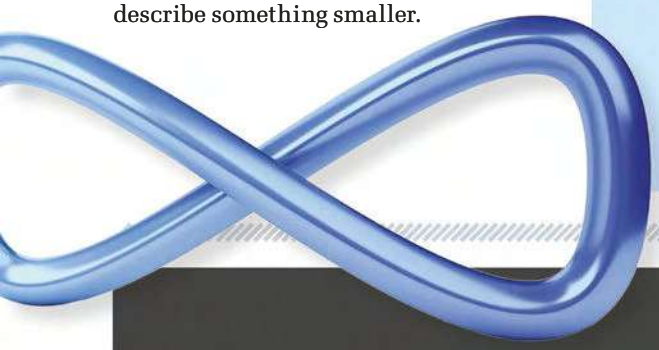
Prime numbers, the Higgs boson, infinity, bets you can't lose, one-way mirrors, coin tosses, circular rainbows, perpetual-motion machines...

DOES TIME EXIST IN SPACE?

Time is a complex subject for physics. Einstein showed that time and space are intimately linked and that the progression of time is relative, not absolute. Although there is nothing in physics that says time must flow in a certain direction, scientists generally agree that time is a very real property of the Universe. Our science is thus based on the assumption that the laws of physics, and the passage of time, exist throughout the Universe.

Are some infinite numbers really bigger than others?

Mathematicians have identified a family of so-called transfinite numbers, which are bigger than the largest finite numbers. The smallest of these is called omega, formed by adding one to each whole number after zero, and continuing forever. And ultimately there is absolute infinity, which is so colossal that attempted descriptions always describe something smaller.



If I throw a ball up vertically on a moving train, will it move away from me?

No – it will land just as if you were standing still. That's because the ball started off in your hand, so was also travelling forward with the speed of the train. Once airborne, it doesn't lose that forward speed, so it keeps up with you and lands in your hand.

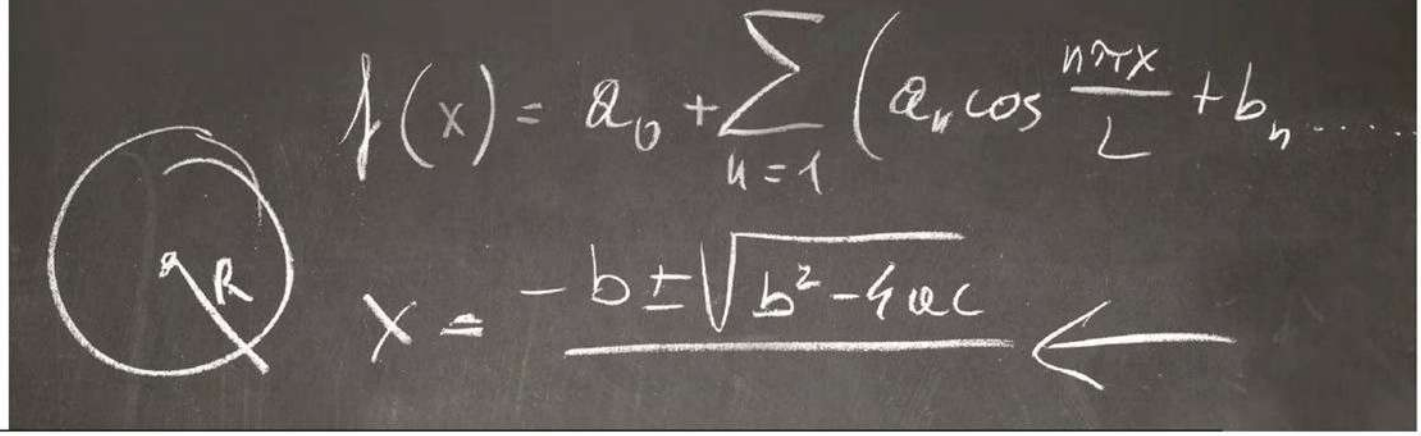
What's the most amazing result in mathematics?

A popular choice is Euler's Identity, which shows that raising the endless number 'e' (roughly 2.718) to the power of pi, multiplied by the impossible square-root of -1, and then adding the result to 1 produces... zero. How such a crazy mix of numbers leads to such a simple result defies common sense.

No less baffling is the Banach-Tarski Paradox, which shows that a solid ball can be cut into five special shapes and re-assembled to make two exact, perfectly solid replicas of the original ball. Admittedly, the shapes have to be pretty special; specifically, they need to be infinitely jagged, which isn't possible in the real world.

Arguably, the craziest of all results does have real-world implications. It's the sum of all the integers, 1+2+3+4 and so on, all the way to infinity. On the face of it, this must add up to infinity. The correct answer, however, isn't even a positive whole number: it's minus 1/12.

This result emerges from something called analytic continuation of the Riemann zeta function. Physicists have successfully tested its implications in theories about the sub-atomic world.



PHOTOS: NASA/HUBBLE SPACE TELESCOPE, ISTOCK X3

TOP TEN

BRITISH UNIVERSITIES FOR MATHS

1. Cambridge
Overall score: 100

2. Oxford
Overall score: 99

3. Imperial College London
Overall score: 97.5

4. St Andrews
Overall score: 96.7

5. Warwick
Overall score: 96.5

6. Durham
Overall score: 96

7. Bath
Overall score: 94.4

8. Dundee
Overall score: 93.7

9. Bristol
Overall score: 93.5

10. London School of Economics
Overall score: 92.4

Source: *The Complete University Guide*. The scores are based on a number of criteria, including entry standards, student satisfaction, quality of research and graduate prospects.

Is there such a thing as a bet you can't lose?

It's possible to place bets that will pay off regardless of the outcome, using a trick called arbitrage. Imagine a cup final involving Chelsea and Spurs. Bookmakers will offer odds for either team to win and, as this represents all the possible outcomes, the odds should tot up to 100 per cent. Yet they don't: it's always more, which is how bookies lock in a profit. But by finding two bookies offering odds that combine to give less than 100 per cent, you can lock in your own profit. If Bookie A is offering evens odds for Chelsea, while Bookie B has Spurs at 5/4, these tot up to 94 per cent. A quick sum then shows that if we put 53 per cent of our money on Chelsea with Bookie A and the rest on Spurs with B, we'll make a profit of 5 per cent, whoever wins.

So why isn't everyone doing this? First, 'arbs' are hard to spot, and they usually last only minutes. And, if the odds change while you're putting your stakes on, the arb becomes a bet – whose outcome, of course, isn't guaranteed. Furthermore, the profit margins are also small, making it all too much trouble for most punters.

How can the Universe be infinite if it is expanding?

The expansion of the visible Universe is the result of the stretching of space between whole clusters of galaxies – a little like coins stuck to an expanding balloon. This stretching effect would still make sense whether the entire Universe were double, 10 times or even infinitely bigger than what we can observe.

IN NUMBERS

2,520

The smallest number that can be evenly divided by all the numbers between one and ten

How do stones skim?

For a pastime dating back at least to the ancient Greeks, it's odd that the science behind skimming stones has only recently attracted scientific interest. After all, there's plenty to ponder. What stops the stones from sinking like, well, stones? And what's the secret to maximising the number of skips?

Some answers emerged in 2004, when a team led by Christophe Clanet of the French National Centre for Scientific Research (CNRS) in Marseille published theoretical and experimental results in the journal *Nature*.

As every skimmer knows, shape, speed and spin-rate are all important. The team showed, however, that it's the angle to the water that is most important in getting plenty of skips. If the stone hits the water too steeply, it plunges in and sinks. Too shallow an angle causes it to slow down, lose energy and fail to bounce back up off the water. According to the team, the ideal angle is around 20° to the water.

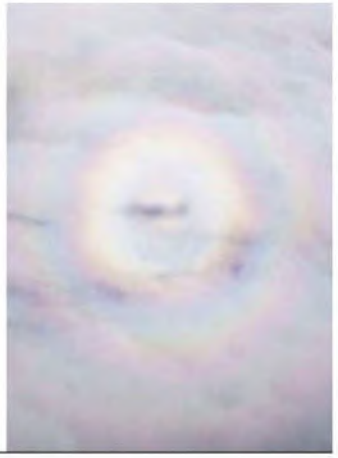
Shape, speed and spin-rate are still important, however. A flat stone is best, with the number of bounces increasing with speed of throw. A high spin-rate also gives the stone gyroscopic stability, helping it to maintain the right angle relative to the water on each bounce.

WHAT MAKES THINGS BURN?

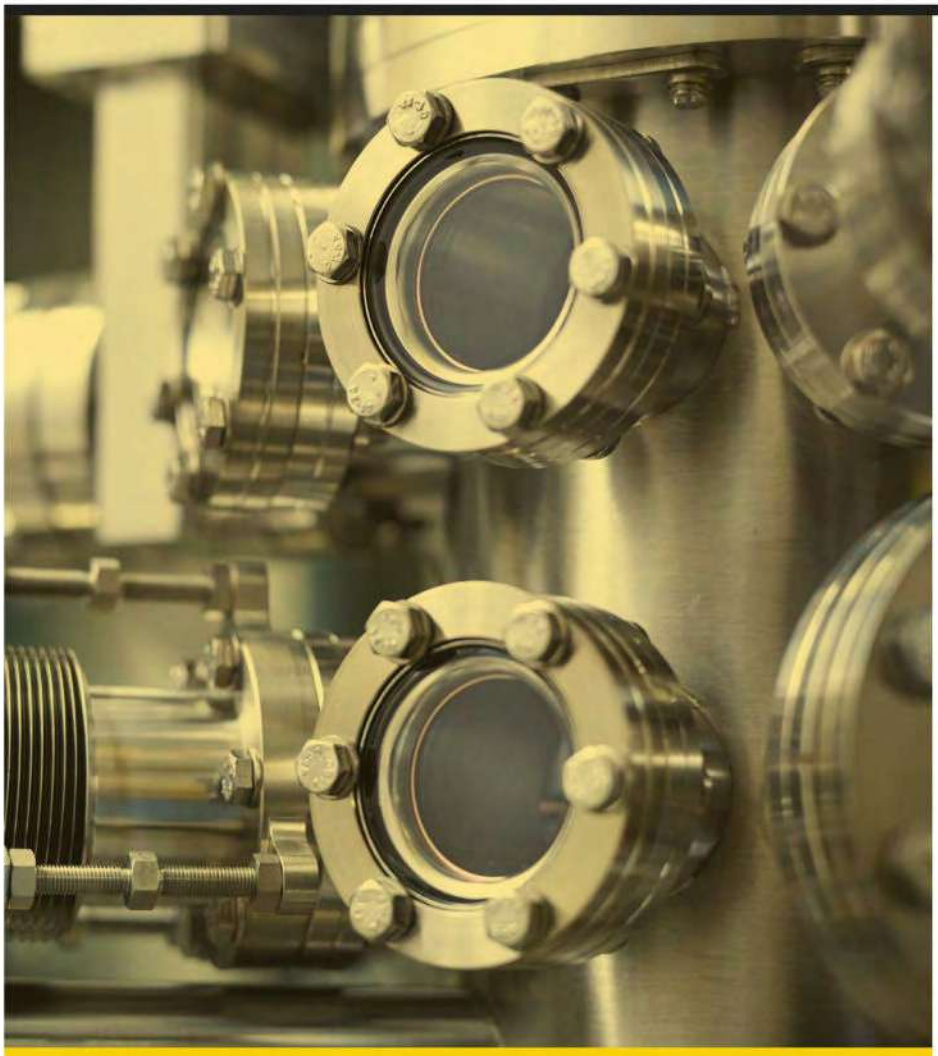
Combustion is simply a type of chemical reaction that occurs between a source of fuel and a source of oxygen, creating heat plus new compounds. A source of energy is often needed to split apart the fuel and oxidiser molecules – for example, a spark. But once the fragments start reacting, the heat produced keeps the process going.

Why are rainbows circular when viewed from an aeroplane?

Rainbows are formed when light emerges from water droplets that are in just the right place for the rays to enter our eyes. Such droplets always lie on a circle facing the Sun. Unless we're airborne we can only see a 'bow', as the ground blocks out the rest.



PHOTOS: ISTOCK X7, GETTY, ALAMY X2, SCIENCE PHOTO LIBRARY



WHAT TEMPERATURE IS A VACUUM?

The temperature of a substance is a measure of the kinetic energy of its constituents. So, for example, nitrogen at room temperature consists of molecules whizzing around with typical speeds of over 1,800km/h. Yet, in principle at least, a vacuum is utterly devoid of constituents, making this definition of temperature problematic.

In practice, however, genuinely perfect vacuums don't exist. Quantum theory implies that even apparently 'empty' space is seething with energy. The 'hardest' vacuum we know of in real-life – that is, the closest to a perfect vacuum – is space, yet even this contains an average of around one particle per cubic metre, plus radiation left behind from the Big Bang. After 14 billion years, this radiation now has an energy corresponding to a temperature of around 3°C above absolute zero (-273°C), making this the temperature of the hardest known vacuum.

DID YOU KNOW?

Albert Einstein failed his original university entrance exam. He passed the maths and physics papers with flying colours, but struggled on the non-science subjects.

What has the discovery of the Higgs boson taught us?

The elementary particle known as the Higgs boson was discovered at the Large Hadron Collider in Geneva in 2012. Most reports of its discovery focused on its role in explaining the origin of mass but, for physicists, the real excitement lay in how it confirmed their beliefs about how the Universe is put together.

For decades they've been searching for a 'theory of everything' to explain all the forces in the Universe, looking for similarities between disparate forces. The problem is that these similarities are sometimes very well hidden. In the 1960s, several theorists, including Peter Higgs (below) at the University of Edinburgh, argued that the apparently radical differences between the weak nuclear force and the electromagnetic force would vanish if a particle with certain properties existed. Later dubbed the Higgs boson, its discovery boosted the confidence of physicists in their strategy for unifying the forces of nature.

PHOTOS: CERN

Why are prime numbers so important?

The clue is surely in the name. Starting with one and the primes, it is possible to create all the other numbers. Ancient Greek mathematician Euclid proved there is an infinite supply of primes and that every number greater than one is either a prime or the result of multiplying a unique combination of primes together.

Given their elemental role as the building blocks of numbers, primes have fascinated mathematicians ever since. This has led to some practical applications of prime numbers – the most famous of which is so-called public key encryption, widely used to keep electronic data secure. Public key encryption relies on the fact that while it's easy to multiply two huge primes together, there's no known way to rapidly do the reverse: breaking apart a huge number into its prime factors. That's not to say that such a method does not exist, but finding the existence of a quick factoring method is the focus of intense research.

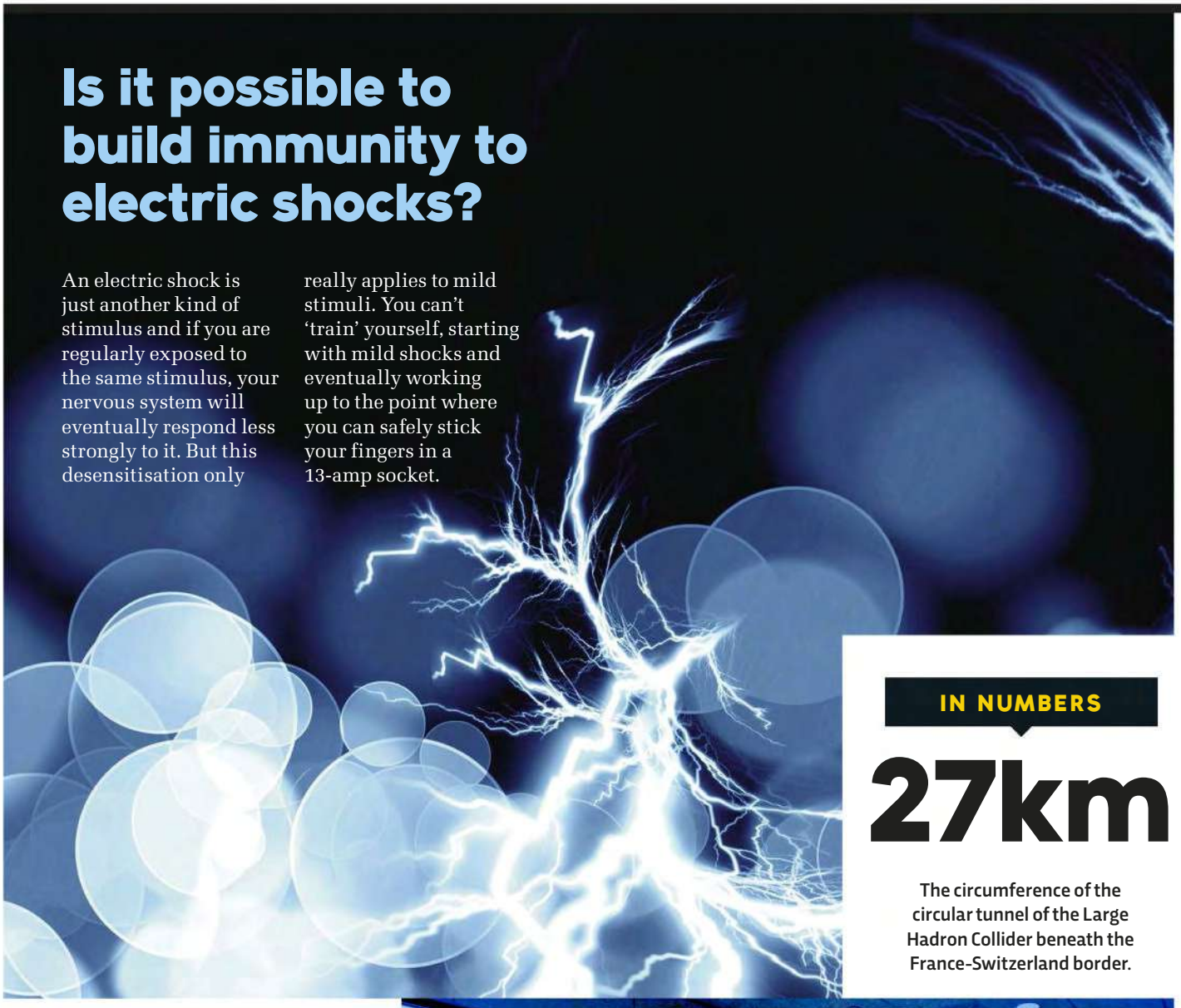
ARE COIN TOSSES REALLY RANDOM?

While a coin toss is regarded as random, it spins in a predictable way. In 2008, a team from the Technical University of Łódź, Poland, analysed the mechanics of a coin tumbling in the air. The study revealed that the coin's behaviour is predictable – until it strikes the floor. At that point, 'chaotic' behaviour sets in, with small differences producing radically different outcomes. This suggests that coin tosses caught in mid-air may have a slight bias, a possibility investigated by Persi Diaconis of Stanford University. He found that caught coins have a slight tendency to face up the same way as when tossed. The bias, though, is incredibly slight. So the outcome of tossing a coin can indeed be seen as random, whether caught in mid-air or allowed to bounce.

PHOTOS: SCIENCE PHOTO LIBRARY, ISTOCK X2

Is it possible to build immunity to electric shocks?

An electric shock is just another kind of stimulus and if you are regularly exposed to the same stimulus, your nervous system will eventually respond less strongly to it. But this desensitisation only really applies to mild stimuli. You can't 'train' yourself, starting with mild shocks and eventually working up to the point where you can safely stick your fingers in a 13-amp socket.



IN NUMBERS

27km

The circumference of the circular tunnel of the Large Hadron Collider beneath the France-Switzerland border.

What makes something transparent?

Whether a substance is transparent depends on how light interacts with its atoms. If they're of the right frequency, an atom's electrons can absorb photons of light, making the matter opaque. However, the atoms of transparent matter enable photons to pass through.

How do one-way mirrors work?

A one-way mirror allows people in one room to observe another via a window coated with a thin layer of reflective material. The trick lies in making this layer both thin enough to see through and thick enough to bounce back any bright light striking it. Then, by keeping the room that's under observation much brighter than the other, it's possible to look into it without being seen.

PHOTOS: ISTOCK X2, ALAMY

CAN SCIENCE EXPLAIN LUCK?

If you throw a die and it falls down, that's not luck, that's gravity. But calculating exactly which number ends face up requires you to know all the forces involved, the movement of the air molecules, and so on. That's much too hard to do in the time it takes for the die to land, so we commonly say that it's down to 'chance'. This means that there are too many parameters to figure out the outcome of the event in the given time – or we can't calculate them accurately enough.

'Luck' is the word we use to describe the particular outcome of a chance event. If a die rolls a six, we might call it good luck; if it rolls a one, we might call it bad luck. But if every number has the same probability of rolling, then 'luck' is just a story we tell ourselves to make sense of the event retrospectively.

Humans are story-telling animals. We look at the world as a narrative, usually with ourselves at its centre. The science of psychology has something to say about why we find luck such an attractive concept, and maths can explain why some random events happen more often than we intuitively feel they should. But physics can't explain luck itself, because it is a fiction of our own making.

DID YOU KNOW?

The air around a lightning strike is the hottest place on Earth. For a split second, temperatures hit 30,000°C – hotter than the surface of the Sun.

What are the chances of two snooker games being identical?

Very slim indeed, because snooker involves so-called chaotic processes in which just small changes produce radically different outcomes. Rough calculations show that if two snooker games are played with the first red ball struck to within a hair's breadth of the exact same position, the games will be hugely different after around half a dozen shots. F

PHOTOS: ISTOCKX3

GOING DOWN THE TUBES

Nope, this isn't the root structure for some fearsome plant. This mass of black tendrils is part of a silk moth caterpillar's respiratory system, which differs dramatically from that of a mammal.

Rather than lungs, insects rely on a tracheal tree, which is a network of tubes that conveys oxygen around their bodies. Air is drawn in through spiracles – openings in an insect's exoskeleton – where it enters the tracheal tree. The branches extend throughout the insect's body, allowing the air to reach all its organs, tissues and cells. Hoops made of chitin – the same material that forms an insect's hard exoskeleton – keep the tubes open so air can flow freely.

David Maitland created this image by using differential light microscopy to magnify the tracheal tree that he found on an Edwardian microscope slide.

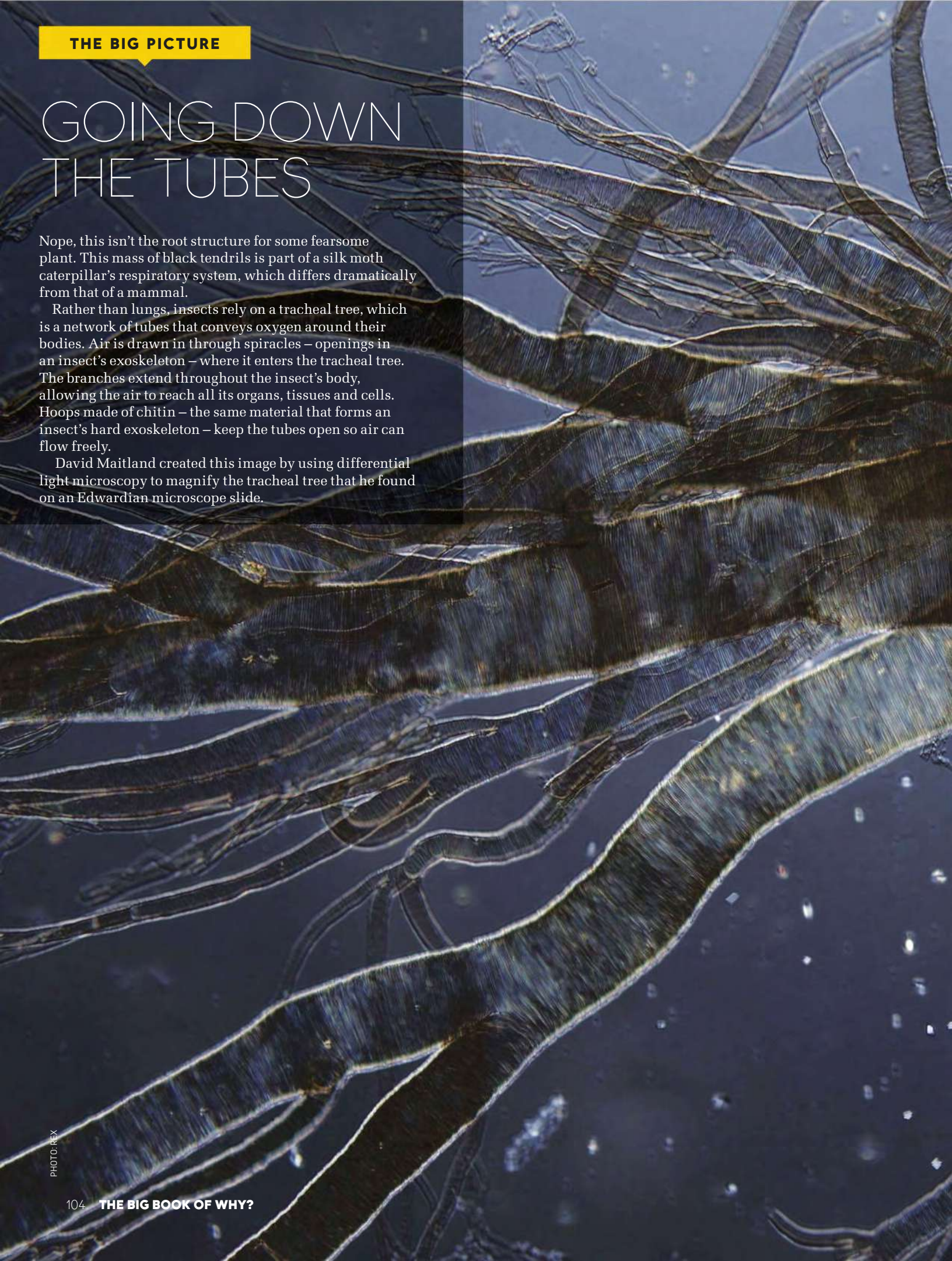


PHOTO: REX

HOW IT WORKS

From robot exoskeletons to solar-powered flight, we reveal the secrets behind how the future world will function...

HOW DOES A FORMULA E CAR WORK?

What lies beneath the exterior of these electric race cars may well define the future of high-octane, single-seater racing

TYRES

The driver gets just five sets of Michelin all-weather grooved 457mm tyres for a one-day event. F1 in comparison, provides the driver with 20 sets for a three-day race weekend: 13 are dry-weather tyres and the rest are wets.

HOW MANY TYRES?

Formula E – 5

Formula 1 – 20

SOUND

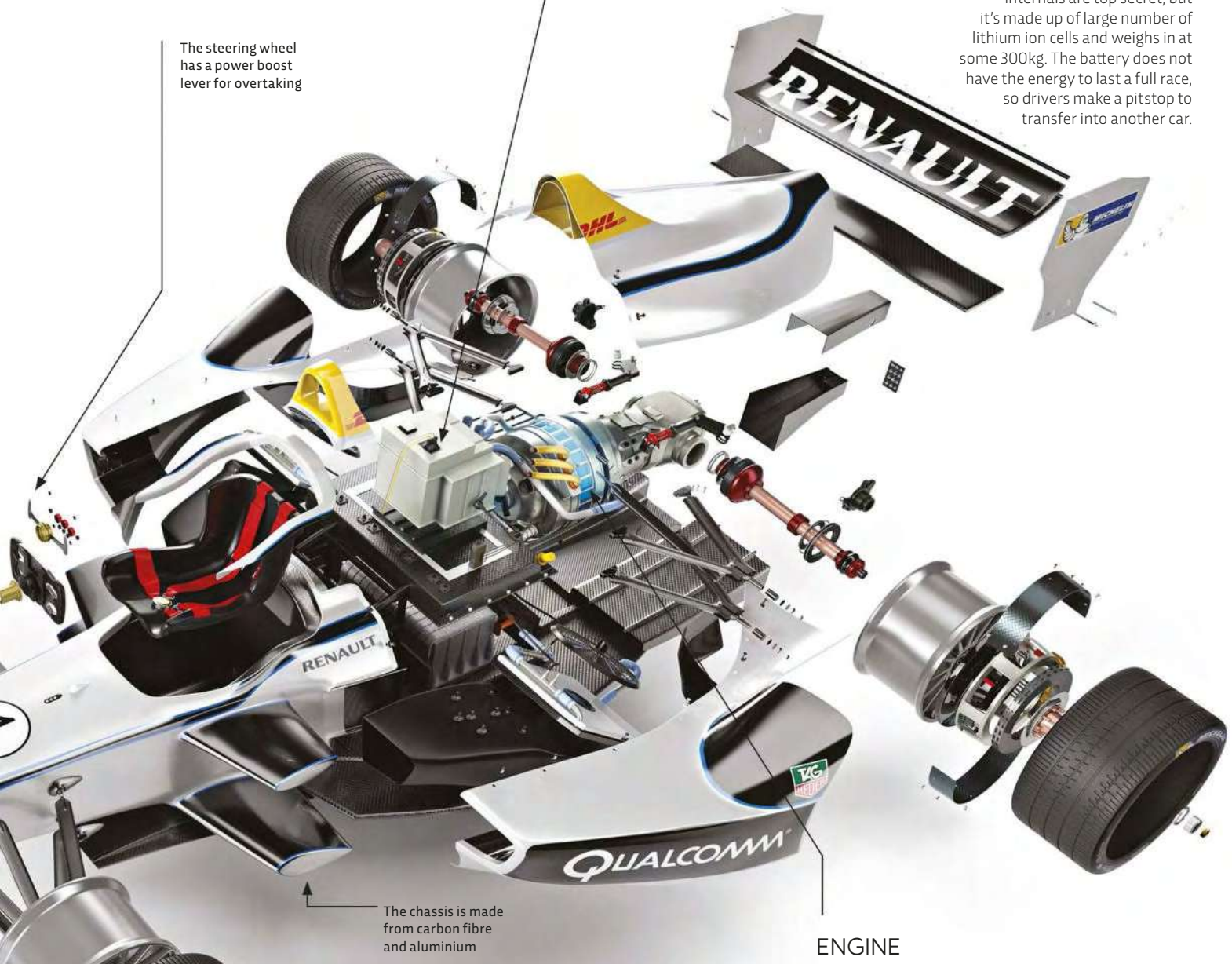
The Formula E car is quieter than F1 vehicles, although still makes some noise. The whirr of the electric motor and gears indicates how fast the car is accelerating.

ILLUSTRATION: GRAHAM MURDOCH

BATTERY

For safety and convenience, the battery is housed in a separate carbon fibre box. Its internals are top secret, but it's made up of large number of lithium ion cells and weighs in at some 300kg. The battery does not have the energy to last a full race, so drivers make a pitstop to transfer into another car.

The steering wheel has a power boost lever for overtaking



The chassis is made from carbon fibre and aluminium

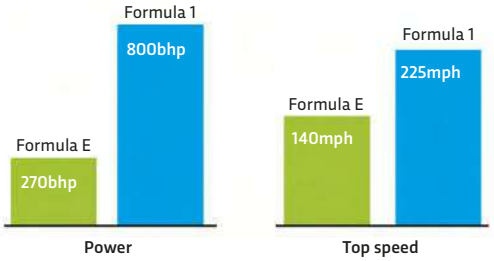
SHAPE

The Formula E car is a little shorter and narrower than an F1 car, while externally they are quite different. Every Formula E car is the same – teams are only allowed to alter the set-up of the standard car. The bodywork optimises aerodynamic efficiency, generating less downforce and has more ground clearance than F1 cars. The driver is cocooned in a 'survival cell', which forms part of the chassis. The cell is made to the same FIA safety standards as F1 cars, complete with a roll hoop, padding inside the cockpit, and front, side and rear crash structures.

ENGINE

The Formula E car has a large battery, tiny electric motor and gearbox. Temperature inside these units increases over the course of a race, so cooling is a critical issue for the Formula E car's performance.

A gearbox is used to increase the torque output from the small motor.



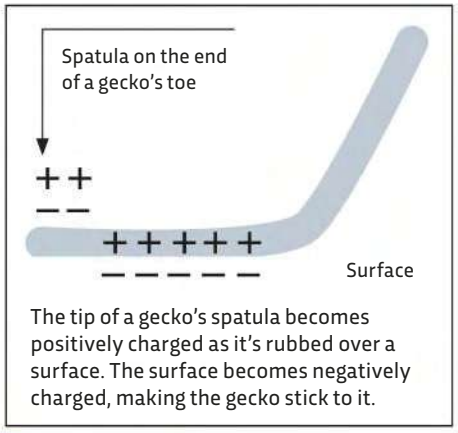
GECKO ADHESION

The extraordinary ability of this particular reptile to cling to surfaces has long mystified observers. New research suggests that it may all be down to electrostatic attraction...

Zoologists have long been fascinated by the gecko's Spider-Man-like ability to cling to walls and ceilings. Until recently, geckos were believed to stick to surfaces by making use of two different forces. One is weak van der Waal's forces, formed from the momentary unequal share of electrons between molecules. The other is capillary action, the attractive force that allows kitchen towel to soak up water.

A team at the University of Waterloo in Canada now offers a third explanation – that electrostatic attraction also plays a role in the reptile's sticky ability. The strong, electrostatic force develops from the stable electron exchange between molecules – this is what makes our hair stand on end and stick to balloons. Scientists discovered that a tokay gecko uses this force by gently dragging its feet across a non-sticky surface and measuring the resulting electric charge. Electron exchange takes place where the tiny spatulas at the ends of each hair-like seta on the gecko's toes make contact with the surface of the material. This creates a measurable force. The team found that when the gecko's toe pad made contact with a surface, the pad became positively charged while the surface became negative, creating electrostatic attraction.

The strength of the electrostatic charge suggests this force is the most important for the gecko's adhesive ability, yet the other forces are likely to be important when geckos climb wet, slippery surfaces, where electrostatic bonds cannot form.



The tip of a gecko's spatula becomes positively charged as it's rubbed over a surface. The surface becomes negatively charged, making the gecko stick to it.

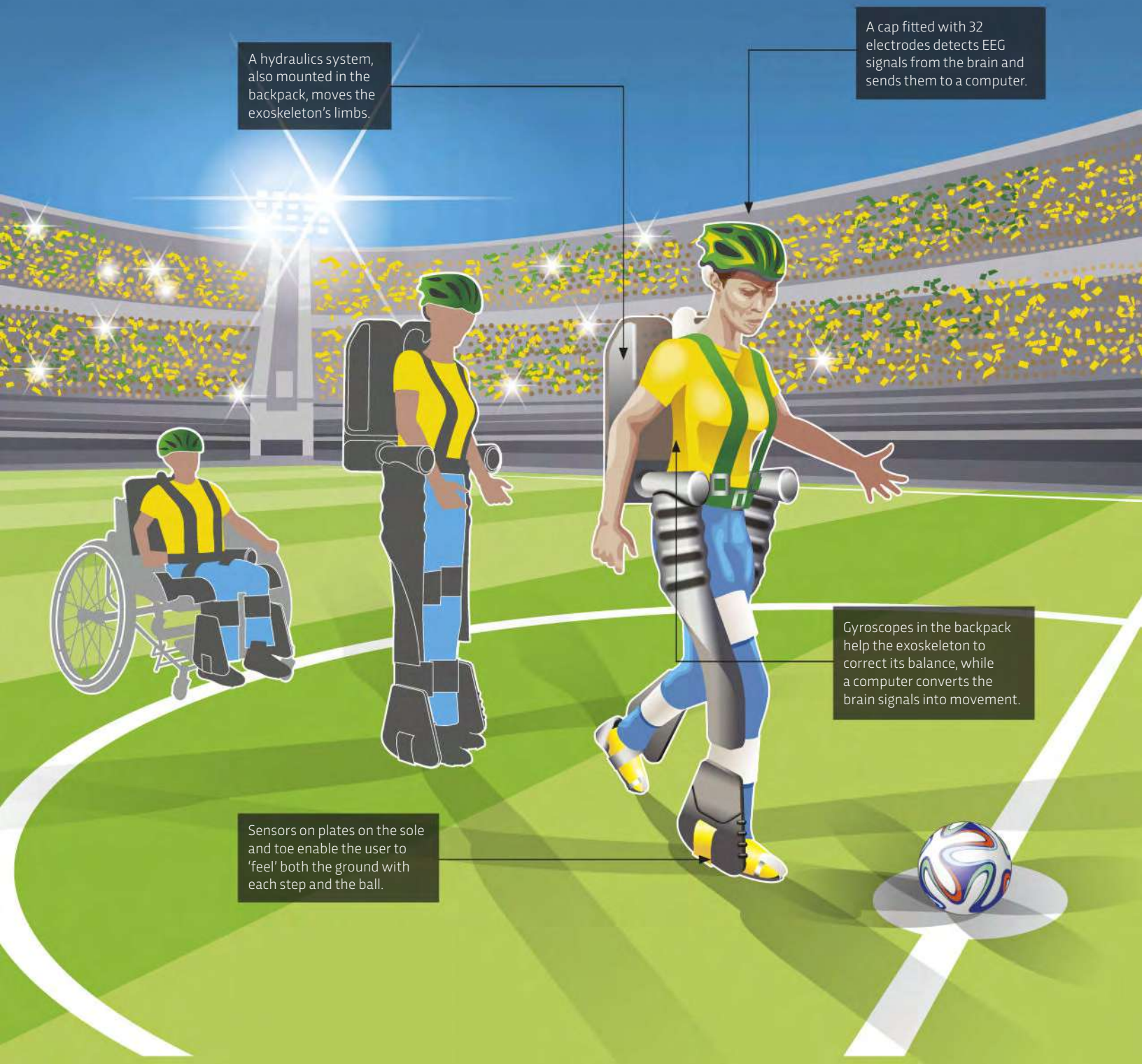
PHOTO: SCIENCE PHOTO LIBRARY X3, ILLUSTRATION: PAUL WESTON

ROBOT EXOSKELETON

As demonstrated at the 2014 FIFA World Cup, this mind-operated exoskeleton enables sufferers of paraplegia to once again take control of their limbs

The 2014 FIFA World Cup opening ceremony was one of the most spectacular of all time and featured a young paraplegic Brazilian kicking a ball across the pitch at the Corinthians Arena in Sao Paulo. This miraculous act was possible thanks to a mind-controlled robotic exoskeleton, made by the Walk Again Project, a collaboration between universities across different continents.

The operator wears a cap that's linked to a computer in the backpack of the suit. The cap picks up brain signals that are created when the user thinks of walking and a computer then converts this information into electrical commands, which then move hydraulic legs. The whole set-up is stabilised by gyroscopes and powered by a battery that sits in the backpack. When the user kicks the football, they'll be able to actually feel it, thanks to sensors in the feet of the suit that trick the brain into thinking the signals came from the real foot.

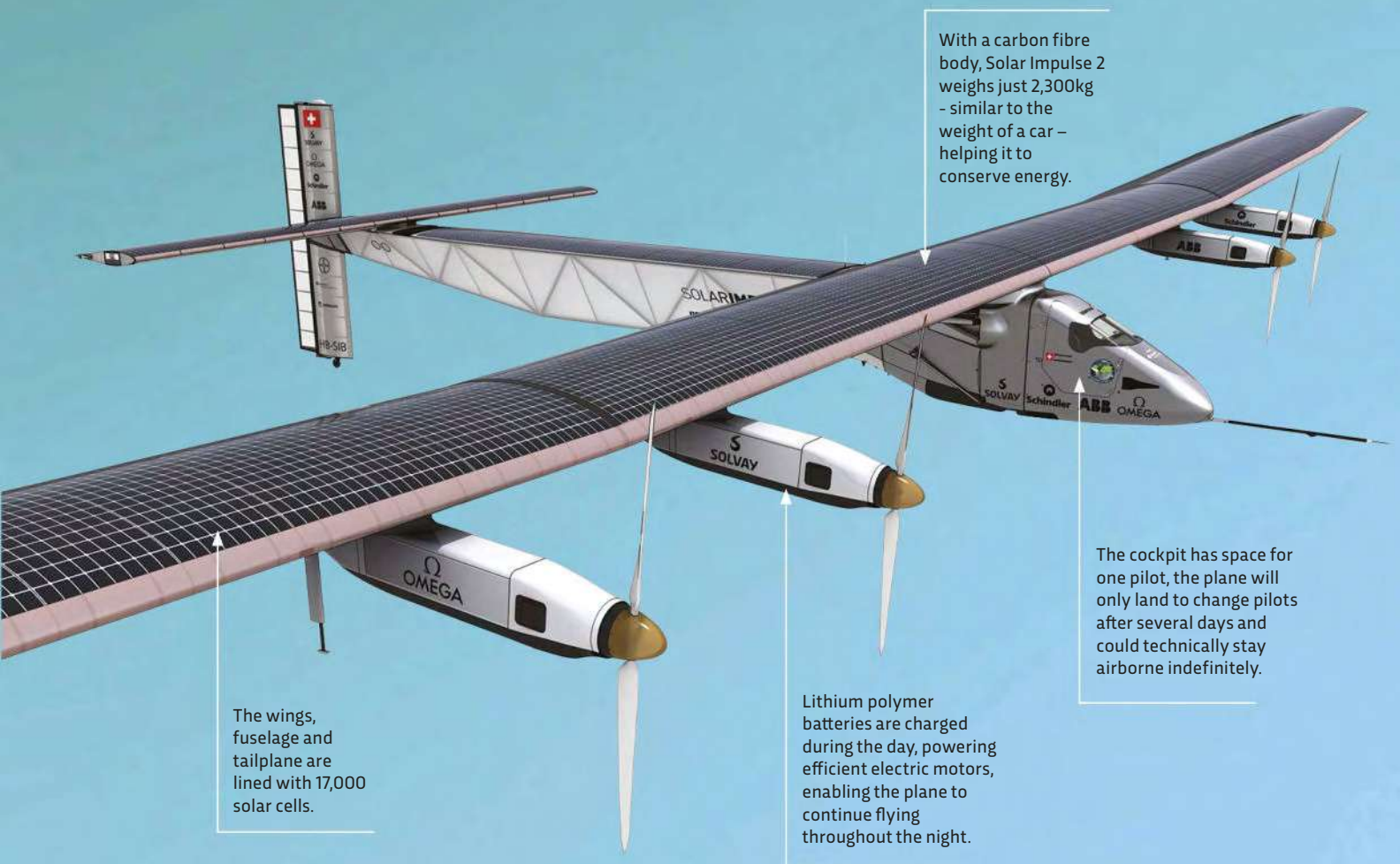


SOLAR IMPULSE 2

Powered by the Sun and only weighing as much as a car, this wide-winged plane can – in theory, at least – traverse the globe without stopping to refuel

With a wingspan of 72m, it's wider than a jumbo jet and yet it only weighs 2.3 tonnes. This is the Solar Impulse 2, a plane that's able to fly around the world non-stop without carrying an ounce of fuel. The wings are lined with over 17,000 solar cells that charge highly efficient lithium batteries. These are housed along the wing and deliver power to four electric motors and propellers.

With a top speed of only 141km/h (88mph), this plane isn't going to break any speed records but, in 2015, the team behind it attempted to circumnavigate the globe to showcase the technology.



WINGSPAN

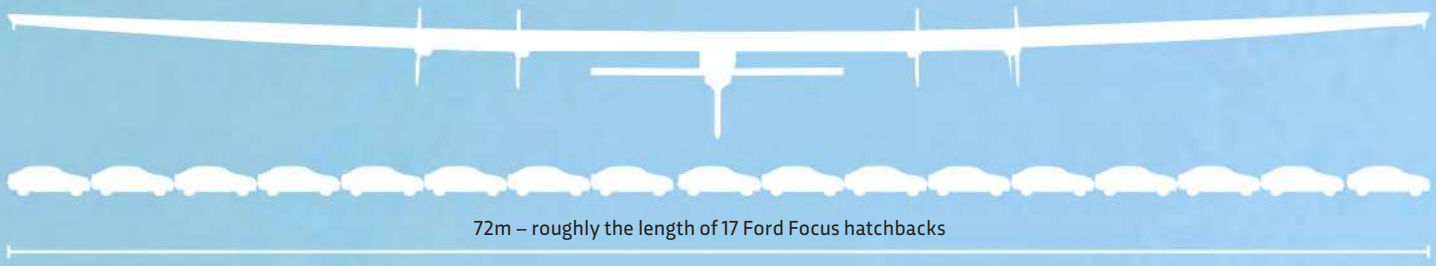


ILLUSTRATION: ACUTE GRAPHICS

SMART CAP

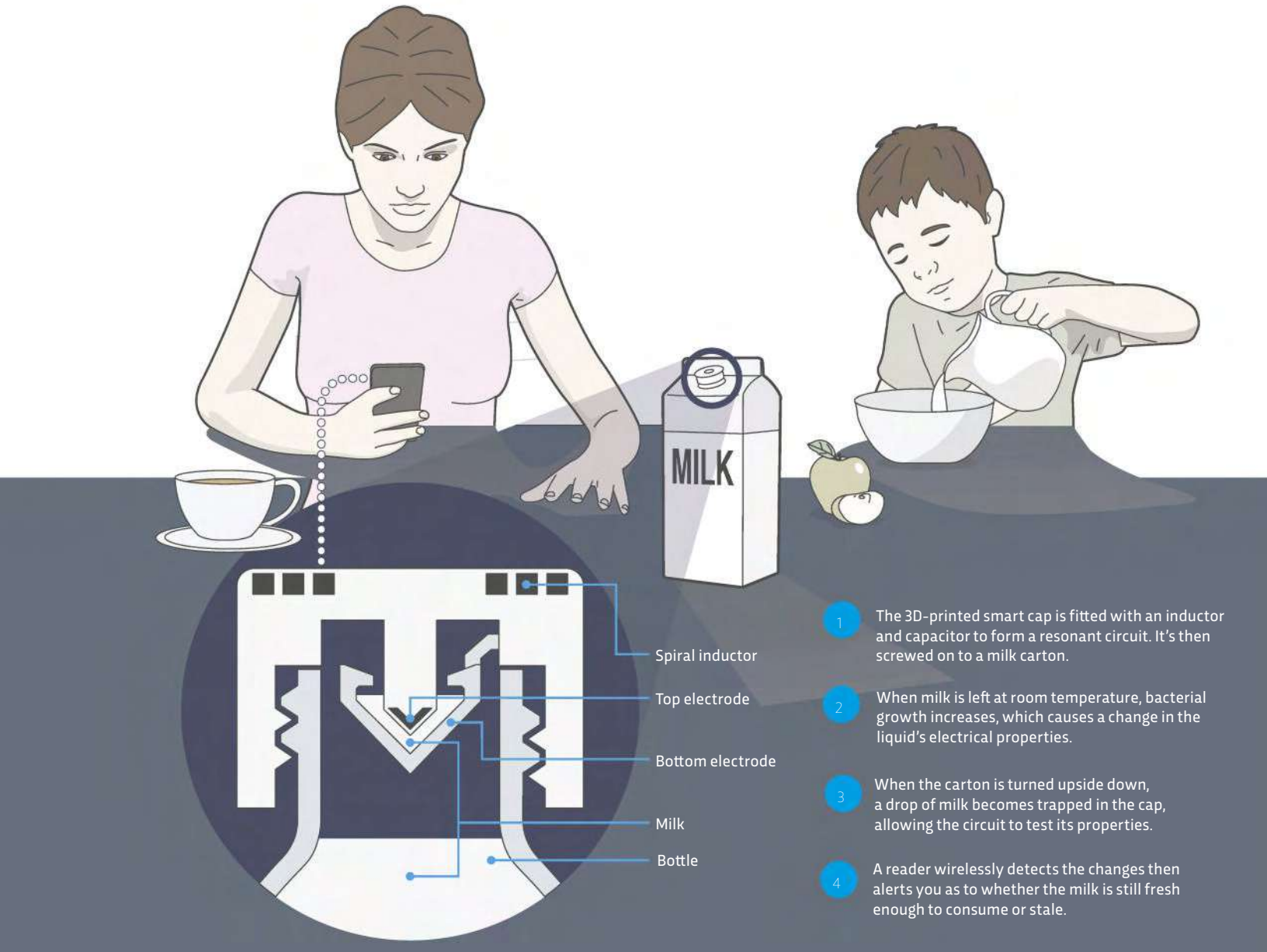
No more will you need to apply nose to milk carton to see if it's still fresh. Introducing the 3D-printed 'smart' bottle cap...

Researchers at the University of California, Berkeley have designed a 3D-printed 'smart' bottle cap that lets you determine whether milk has turned sour – without needing to give it a sniff. This is the first time that working electronic components have been incorporated into a 3D-printed device. The specialised cap can be placed onto ordinary milk or juice cartons to establish when a liquid has gone off.

The main body of the cap is made from plastic polymers, with a conductive silver tube hidden inside. Electronics fitted to this tube turn it into a fully functioning circuit.

When a carton is quickly inverted, milk enters the circuit's capacitor, becoming trapped inside. Electrical signals in the liquid are analysed in real-time using an inductive reader, to measure the rate of bacterial growth.

In future, this technology could be embedded in a wide variety of packaging. "You could imagine a scenario where you can use your cellphone to check the freshness of food while it's still on the store shelves," says the study's senior author Liwei Lin.



1. The 3D-printed smart cap is fitted with an inductor and capacitor to form a resonant circuit. It's then screwed on to a milk carton.
2. When milk is left at room temperature, bacterial growth increases, which causes a change in the liquid's electrical properties.
3. When the carton is turned upside down, a drop of milk becomes trapped in the cap, allowing the circuit to test its properties.
4. A reader wirelessly detects the changes then alerts you as to whether the milk is still fresh enough to consume or stale.

OUT OF THE BLUE

In April 2015, beaches on the west coast of the US were transformed into a translucent carpet of bizarre blue creatures. Although closely resembling jellyfish, each of these *Velella velella* is actually composed of a colony of individual animals. Their prey – usually plankton – is caught using stinging tentacles, but they are not considered dangerous to humans.

V. velella ride currents with the aid of a sail made from a substance called chitin. This sail gives them their common name of 'by-the-wind-sailors'.

"I find it both incredible and tragic that millions of these beautiful and delicate floating colonial organisms, with their specialised structures for sailing, feeding and reproduction, are adrift out in the open sea," says Dr Steven Rumrill of the Oregon Institute of Marine Biology. "And then, by some nuance of the winds, they become concentrated along the shore and cast up on the beaches where they dry out, die, and become a spectacle for beach walkers."

PHOTO: TIFFANY BOOTHE/SEASIDE AQUARIUM

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